The Leyden and Stockholm Papyri

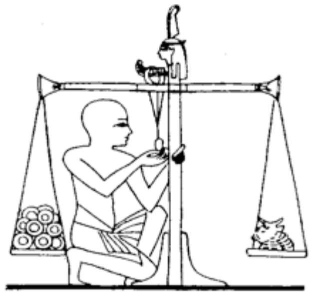
Greco-Egyptian Chemical Documents From the Early 4th Century AD

An English Translation with Brief Notes by

Earle Radcliffe Caley

Edited, with a New General Introduction, A Note on Techniques, and a Materials Index by

William B. Jensen



Oesper Collections in the History of Chemistry
University of Cincinnati
Cincinnati, OH
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1900-1984

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Contents

Illustrations

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I
General Introduction

1.1 The Oldest Chemical Documents

Sometime around 1828 a considerable number of papyri were recovered (presumably by grave robbers) from burial sites near Thebes in central Egypt, many of which were subsequently acquired by Johann d'Anastasy, the Swedish-Norwegian Vice Council at Alexandria. These were not in the form of rolls written in ancient hieroglyphics but rather in the form of separate numbered sheets or codices written in Greek, indicating that the documents and burials were from the Greco-Roman period and probably dated from sometime around the late 3rd or early 4th century AD. The papyri in question were in remarkably good condition, due in part to their having been placed either in tightly sealed coffins or in sealed stone containers, and, in part, because they were, at the time of the original burials, brand new, having been especially copied for that purpose as so-called "Totenbeigaben" or death offerings intended to accompany and serve the deceased in the afterlife. The following year d'Anastasy sold 24 of these papyri to the Museum of Antiquities at the University of Leyden, and in 1832 he made a gift of the remaining items to the Swedish Royal Academy of Antiquities (1).

In 1830 Caspar Reuvens, the Director of the Leyden University Museum, published a descriptive account of the museum's Greco-Egyptian holdings in which he noted that one of the papyri in the newly acquired d'Anastasy collection, which had been given the number 9 in d'Anastasy's original catalog and the number 66 in Reuvens' own listing, dealt almost exclusively with chemical recipes (2). Reuvens characterized it as being "alchemical" in nature and also included some brief extracts. It was, however, not until 1869 that the existence of the Leyden papyrus was finally brought to the attention of chemical historians, when the German chemist and historian, Hermann Kopp, included a description of

the document, based on Reuvens' earlier summary of its contents, in the first volume of his *Beiträge zur Geschichte der Chemie,* though he rather surprisingly made no reference to it in his later 1886 monograph *Alchemie in älterer und neuerer Zeit* (3).

In 1885 the French chemist and chemical historian, Pierre Marcellin Berthelot, made use of the Leyden papyrus in his speculative account of the origins of Greco-Egyptian alchemy (4). Like Kopp, his knowledge of this work was based largely on Reuvens' earlier summary, though that same year Conradus Leemans, Reuvens' successor as the Director of the Leyden Museum, finally published the complete text of the original papyrus in Latin translation (5). Since this appeared as part of a two-volume collection of translations of other papyri, Leemans gave each of them a distinguishing letter, whence the name "Leyden papyrus X." Two years later Berthelot published a French translation of Leemans' text along with a detailed chemical commentary (6), and in 1906 he also published a reproduction of the original Greek text as well (7).

Meanwhile, the papyri given to the Swedish Royal Academy of Antiquities languished in its archives until their transfer to the Victoria Museum at Uppsala in 1906, when they came to the attention of Otto Lagercrantz, who discovered that they also contained a collection of chemical recipes similar to that of the Leyden papyrus, and who finally published the original text with a German translation in 1913 (8). That same year the Austrian chemist and chemical historian, Edmund von Lippmann, published a detailed article describing and comparing both papyri, which eventually served as the basis of his account of these documents in his epic 1919 work *Entstehung und Ausbreitung der Alchemie* (1, 9).

It was not until 1924, however, and the appearance of John Maxson Stillman's *Story of Early Chemistry* that an English-language account of these papyri was finally published (10). Indeed, Stillman's book was, and still remains, the single best English-language summary of the work of such classic chemical historians as Kopp, Berthelot and von Lippmann, none of whose original books were ever translated. Though Stillman also gave a partial translation of several of the recipes from both papyri, it was not until 1926 and 1927 that Earle Caley finally provided a set of

complete translations in the form of a series of articles published in the newly founded *Journal of Chemical Education*, and it is these articles and translations which form the basis of this present edition (11, 12).

As a reading of these translations quickly reveals, neither papyrus contains the mystical symbolism and allegorical indirection so typical of the true alchemical literature. Rather they consist largely of simple, short recipes. In the case of the Leyden papyrus these focus primarily on the preparation of various metal alloys – many of which are intended to imitate the appearance of either gold or silver – for use in making jewelry, in gilding, or in metallic writing, while a few others deal instead with dyes of various sorts. The contents of the Stockholm papyrus have the same form, but focus more on dyeing and the imitation of various precious stones and gems. Both papyri explicitly acknowledge that the alloys and gems which they describe are imitations and not the real thing. Indeed, so simple and safe are some of the recipes that they have actually been proposed as potential laboratory preparations for use in connection with a modern-day history of chemistry course (13).

Kopp, in his original description of the Leyden papyrus, referred to it as "Die älteste chemische Handschrift," – the oldest chemical manuscript – a characterization that has been generally accepted by most subsequent chemical historians. Thus it is somewhat ironic that, even as Caley was making his translations in late 1925, that status was being seriously challenged by work in the field of Assyriology. For that same year the British Assyriologist, R. Campbell Thompson, and the German Assyriologist, H. Zimmern, each independently published transliterations and translations of several cuneiform tablets dating from the 7th century BC containing practical recipes for the preparation of colored glasses (14, 15) – a subject which is surely as legitimately chemical in content as are the preparations of the alloys, inks, dyes and artificial gems described in the Leyden and Stockholm papyri. Though these translations are now over 85 years old, they have remained relatively unknown to most historians of chemistry, despite the more recent publication of an impressive and definitive edition of the relevant cuneiform texts by Oppenheim *et al.* (16).

1.2 Problems of Interpretation

As noted above, Berthelot's original interest in the Leyden papyrus lay in its potential relevance to explaining the origins of Greco-Egyptian alchemy. It was speculated that this papyrus had escaped the destruction of documents relating to the manufacture and imitation of gold and silver supposedly ordered by the Emperor Diocletian around 290 AD – in order to prevent the debasing of currency and the financing of insurrections – because it had been secreted in the mummy case of the "Egyptian priest" who had originally owned it. It was further speculated that many of the other papyri belonging to the d'Anastasy collection had also come from the same source and, since several of them dealt with magic, it was inferred by Berthelot, Lagercrantz, Diel, and other early commentators, that the original owner of both the Leyden and Stockholm papyri had coupled his practical chemical knowledge with magical and mystical practices as well, thus providing the essential ingredients for the emergence of alchemy (17).

Though the classic studies of Mircea Eliade have demonstrated strong parallels between the hylozoism and sexual imagery of alchemy and that associated with both ancient metallurgy and its practice in contemporary primitive societies, the almost total absence of anthropomorphisms, allegory, and pseudo-religious and/or mystical elements in both the Leyden and Stockholm papyri raises serious questions concerning their traditional characterization as proto-alchemical documents by Berthelot and most subsequent chemical historians (18). Indeed, as Stillman noted many years ago, if it is true that the original owner of the Leyden and Stockholm papyri was willing to publicly obfuscate his private practical chemical knowledge through the affectation of charms, rituals, and other pseudo-religious and/or magical practices, then this almost total bifurcation between the practical and magical makes it difficult to avoid the conclusion that the practice of the latter must have also involved a significant level of conscious charlatanism, since from the contents of these papyri (10):

... we may reasonably infer that these operators, however willing they were to deceive others, were not self-deceived in the character

of their work, nor confused in these operations to any considerable extent by metaphysical or mystical ideas.

If, instead of wasting our time fruitlessly speculating about the unknown authors and/or original owners of these papyri, we concentrate instead on their format and contents, then it is far more logical to consider them as a part of a tradition of practical recipe books intended for metal workers, jewelers, dyers, and artisans, rather than as proto-alchemical documents – a practical tradition which extents back in time to the Assyrian cuneiform tablets dealing with glass recipes, mentioned in the previous section, and forward in time through an almost continuous tradition of medieval recipe books intended for artists and craftsmen, of which the most famous are the *Compositiones variae* (c. 790 AD) (19), the *Mappae clavicule* (c. 810 AD) (20), the *De diversis artibus* of Theophilus (c. 1100) (21), and the *De coloribus et artibus Romanorum* of Eraclius (c. 1150). Indeed, the parallels between the Leyden and Stockholm papyri and these later medieval recipe books were briefly noted by von Lippmann as early as 1919 (22), were further elaborated on by Johnson in the 1930s (19, 25), and were also consistently maintained and developed in the writings of the late Cyril Stanley Smith (20, 21). A feel for the richness of this later medieval tradition may be obtained through an examination of Clarke's recent bibliographic study of its surviving manuscript sources (23).

In keeping with this alternative interpretation, it is also of interest to note that Lindsay's 1970 study of the origins of alchemy in Greco-Roman Egypt, unlike Berthelot's original study of 1885, mentions the Leyden and Stockholm papyri only in passing and then only in the chapter on "Ancient and Contemporary Crafts" (24). Likewise, the late Robert Multhauf, in his classic monograph on *The Origins of Chemistry*, repeatedly characterized the Leyden papyrus as an "Egyptian jeweler's recipe book" and essentially dismissed the earlier speculations of Berthelot concerning secret priestly monopolies and temple rites dealing with goldsmithing and metallurgy (25):

The older view that goldsmithing was secret work in which the Egyptian priests themselves were involved is not probable. The

Egyptian temples did maintain craftsmen in jewelry making, and the Crown did attempt to control gold production to the point of monopoly, but it is doubtful that such monopolies were consistently maintained over long eras of Egyptian history. We know that votive offerings and amulets in the form of jewelry were sold in booths in the neighborhood of temples. Amulets were considered magical, and it seems to have been the making of amulets rather than jewelry making per se, which was secret work in which the priests themselves may have been involved.

Of course the above conclusion concerning the nature of the Leyden and Stockholm papyri does not preclude the conjecture that the earliest alchemists were almost certainly aware of many of the same the recipes, which they then interpreted and elaborated upon in pursuit of their own particular theoretical fantasies. Indeed, one of the most suggestive counter-arguments to the conclusion that these papyri are merely practical recipe books intended for jewelers and craftsmen is based on that fact that 27 similar recipes dealing with metal alloys and dyes are found in a work entitled *Physica et mystica,* written by a 3rd century BC magician and alchemist by the name of Bolos of Mendes, who wrote under the pseudonym of Democritus, and who is obliquely referred to (via a writer named Anaxilaus) in Recipe 2 of the Stockholm papyrus dealing with the purification of copper. However, as pointed out by Multhauf, the recipes in the *Physica et mystica* are (25):

... much less precise than those in the Leyden papyrus X, to a degree which makes it uncertain that they are practical and not merely literary prescriptions ... [Bolos] gives the reader a choice of ingredients, many of which have resisted decipherment into the terms of modern chemistry.

In addition, the *Physica et mystica* contains long digressions dealing with magic and theory – in short all of the ingredients typical of the alchemical literature but which are so pointedly missing from the Stockholm and Leyden papyri.

There are, in fact, tantalizing hints that the *Physica et mystica* is related to an even older literary genre known as the "Baphika"

literature and later as "Books of Secrets," which combined practical recipes with magical and religious charms and rituals (25). Like the closely related practical recipe books for craftsmen and artists, it has an almost continuous tradition which extends through the late Middle Ages and the Renaissance, where it eventually further mutated into a genre of popular science writing known as "natural magic," which consisted largely of collections of practical recipes, amusing experiments, magic tricks, and mathematical puzzles, and which, in turn, persisted well into the 19th century (26-28). A typical example from the 16th century is the famous *Magia naturalis* of Giambattista della Porta, which is readily available as a modern photo-reproduction of the English translation of 1658 (29). Like our two papyri, this contains sections dealing with recipes for both the counterfeiting of gold and of precious stones, though the recipes in the latter section do not seem to share much in common with those found in the Stockholm papyrus.

There is even evidence that a writer such as Pliny may have derived some of the information in his epic *Naturalis historiae* from this earlier literature (25). Writing more than two centuries before the date of the Stockholm papyrus, Pliny explicitly noted the existence of a long and established literary tradition dealing with the counterfeiting of gems and precious stones (30):

Nay, even more than this, there are books in existence, the authors of which I forbear to name, which give instructions how to stain crystal in such a way as to imitate smaragdus and other transparent stones, how to make sardonyx of sarda, and other gems in a similar manner. Indeed, there is no other kind of fraud practiced by which larger profits are made.

Of course no one would ever classify Pliny as either a magician or an alchemist and, in a similar fashion, the fact that the unknown compiler of the Leyden and Stockholm papyri mentions pseudo-Democritus in passing no more proves that he was a practicing alchemist than his cribbing from Dioscorides proves that he was a physician or his citation of Julian Africanus proves that he was an early Christian philosopher. The same goes for the reference to to one Phimenas in recipe 84 of the Leyden papyrus. This is

thought to refer to Phimenas of Sais, of whom little or nothing is known. With little justification Berthelot claimed that this writer was identical to a 1st century Egyptian magician by the name of Pammenes, who is sometimes referred to by later alchemical writers, again on the questionable grounds that anyone who writes on the subject of gold and metallic alloys must automatically be an alchemist as well. However, what these literary references do suggest is that the compiler of the papyri was probably better educated and of greater social status than a common craftsman, as does the high quality of the burial papyri themselves.

Even more speculative is the attempt by some commentators to explain away the absence of any theoretical or mystical elements in the papyri by postulating that they are the practical parts of a multi-volume alchemical treatise whose theoretical part has conveniently failed to survive (31). While this persistent practical emphasis in the papyri does not necessarily imply that any unexpressed views on the nature of the chemical transformations described in their recipes, which their author may or may not of held in private, were necessarily more rational than those of the true alchemists, one must further consider that there is implicit evidence in the wording of several of them that their author had a crude understanding of the distinction between a mixture or alloy, on the one hand, and a pure metal, on the other (see, for example, Recipes 8, 23, 26, 32, 38, 42, 43, and 44 of the Leyden papyrus).

Indeed, all of these attempts to force an alchemical interpretation on the Leyden and Stockholm papyri suffer from the common defect that they selectively focus on only those recipes dealing with metals and alloys, while simultaneously ignoring the fact that both papyri also contain recipes dealing with the dying of wool – a mundane subject hardly in keeping with the focus of later alchemical literature – and the same is equally true of the recipes for the fabrication of gems and precious stones found in the Stockholm papyrus. Nevertheless, it has been argued by some that these latter two topics are not without relevance to the origins of alchemy.

One of the implicit themes of the Stockholm papyrus is the parallelism between the use of alum, vinegar and other materials to corrode or prepare the surfaces of various crystals and stones prior to dyeing them different colors and the use of various mordants

when preparing wool for the same purpose. This has led to the theory that Greco-Egyptian alchemy was born of an attempt to extend this analogy to the dyeing or coloration of metals as well, initially using surface effects similar to those employed in modern-day bronzing techniques – a suggestion first put forth by the American chemist, Arthur John Hopkins, in 1902 (32). Alchemy arose when, at some point, this analogy passed over that tenuous boundary which, in the words of Joseph Needham, separates the art of "aurifiction" from the fantasy of "aurifacation." While there is certainly ample evidence for Hopkins' so-called "color theory" of alchemy in both the true Greco-Egyptian alchemical literature and in the later Islamic and European alchemical literature, I must confess that, in my own reading of the papyri, I do not find that the dyeing analogy is particularly prominent among those recipes dealing with metals and metallic alloys.

Two final observations concerning the recipes for dyeing are worthy of note. The first concerns the curious fact that the vast majority of these recipes refer to the dyeing of wool, even though linen was by far the favored textile used in ancient Egypt, and the second has to do with the Egyptian mastery of mordants to obtain color variations using the same dye solution – a mastery which had amazed Pliny more than two centuries earlier (30):

In Egypt garments are dyed according to a remarkable process. They are first cleaned, then soaked, not in dye, but in various substances that absorb dye. These substances do not at first show in the materials, but when the materials have been dipped into the dyeing tun, they can be removed, after being stirred about, completely dyed. The most wonderful thing about this is that, although the tun contains only one kind of dye, the materials suddenly appear dyed different colors, according to the nature of the dye-absorbing substances used, and these colors are not only resistant to washing, but materials so dyed actually wear better.

1.3 This Edition

Almost from the date of its publication, Berthelot's original French translation of the Leyden papyrus became the target of severe criti-

cism, especially from the pen of the Austrian chemical historian, Edmund von Lippmann (9, 17), though it is not always clear just how much of this was directed at the contents of the translation *per se*, how much at Berthelot's failure to provide the kind of critical scholarly apparatus commonly used by classicists and archeologists, how much at errors in the transcription of the original Greek text, and how much at Berthelot's interpretation of their relevance for the origins of alchemy. Similar criticisms were also made by the modern scholar Robert Halleux, who published revised and definitive French translations of both papyri in 1981 (33). However, these have never been translated into English, and so we must continue to rely on Caley's original translations of the French and German versions provided by Berthelot and Lagercrantz so many years ago. This is in keeping with the ultimate goal of this small volume, which is to rescue the Caley translations from the moldering back issues of the *Journal of Chemical Education,* and to make them more readily available to students of chemistry and the general reader, rather than to provide a definitive scholarly English text for specialists in the classics and Egyptology.

In preparing this new edition of Caley's two-part English translation of the Leyden and Stockholm papyri, we have eliminated those few introductory paragraphs of his original articles which dealt with the history of each papyrus, as they were lacking in detail and have now been rendered redundant by this new general introduction. We have, however, retained those portions which dealt with the physical description of each papyrus, as well as those sections containing Caley's notes and concluding commentaries, though all of these have now been numbered and relabeled in keeping with the present chapter format used in this brief monograph.

From a purely chemical standpoint, much could be done to expand on Caley's rather terse notes on the various materials used in the recipes. For example, in his definitive edition, Halleux, has constructed a Greek-French lexicon of the various materials mentioned which is correlated with the line numbers of the original manuscripts (a device used by classical scholars to allow for unambiguous cross-comparison between differently paginated printed editions of a given work) and with references to the materials in

question in both other classical sources and in more recent reference works. In keeping with its more popular intent, Caley did not use line numbers in his translation and I have instead provided a materials index which is correlated with the recipe numbers, though these do not necessarily coincide with those used by Halleux due to differences in opinion on how to divide up the original texts.

Though nowhere near as thorough as Halleux's lexicon, this index should at least give the reader a bird's eye overview of the breath of materials cited in the papyri, as well as their frequency of use. Indeed, it reveals that 105 materials of mineral origin are mentioned, 88 of plant origin, and 16 of animal origin. Among the most frequently cited in the mineral category are alum, copper, crystal, and gold (though often as a color rather than as a material), whereas alkanet, archil and especially vinegar are the winners in the plant category, and urine and wool in the animal category.

As may be seen from a reading of Caley's brief notes and a glance at Halleux's lexicon, there are still several materials mentioned in the papyri which have not been unambiguously identified and which present a problem when sorting them into the categories of mineral, plant or animal. Their proper identification is surely a research problem worthy of pursuit by some future chemical or botanical archeologist (34). Perhaps the most pressing of these is the problem of unambiguously identifying the naturally occurring crystal used in so many of the recipes for the imitation of gems and precious stones (35). In addition, there is also a need to create a list of synonyms, since there is little doubt that the same material is often cited under a variety of alternative names.

What else remains to be done? To the best of my knowledge no one has attempted so far to try and replicate most of these recipes in the modern laboratory. While those involving the dyeing of wool with extracted plant pigments would probably prove unexceptional, those involving the dyeing of crystals are certainly worth looking into (36). Likewise, to the best of my knowledge, no one has so far attempted to correlate the recipes with the composition of actual surviving Egyptian artifacts from the Greco-Roman period in order to determine whether they had widespread application or were simply unique to the original owner of the pa-

pyri. Here again the discovery of objects corresponding to the dyed crystals would probably prove the most distinctive (37).

1.4 The Translator

In concluding this introduction, it may be of interest to the reader to learn a little about the life and career of the author of these English translations, Earle Radcliffe Caley. Born on 14 May 1900 in Cleveland, Ohio, Caley began his university training at the Case Institute of Technology, but transferred after two years to Baldwin-Wallace College, from which he received his B.S. degree in chemistry in 1923. After teaching high school science for a year, he began graduate work in analytical chemistry at Ohio State University at Columbus, receiving his Ph.D. degree in 1928 for work on the analytical determination of the element sodium done under the supervision of Professor Charles Foulk. From 1928 to 1942 Caley served on the faculty of Princeton University and from 1942 to 1946 as an industrial chemist with the Wallace Laboratories of New Brunswick, New Jersey. In 1946 he returned once more to Ohio State University as Associate Professor of Analytical Chemistry, where he remained until his retirement in 1970. He passed away at his home in Columbus, Ohio, fourteen years later, in February of 1984 at age 83 (38).

Caley's interest in the history of ancient chemistry and metallurgy seems to have developed quite early since the translations appearing in this volume were done while he was still a graduate student at Ohio State and were undoubtedly a by-product of his master's thesis, *The Metals and their Compounds in Ancient Times*, which he completed in 1925 (39). This interest was further reenforced during his years at Princeton by a growing fascination with the archeological applications of analytical chemistry, largely as a result of having received the opportunity in 1937 to serve as a chemist for the archeological staff then conducting excavations of the ancient public Agora in Athens, Greece. Caley's work on this project soon revealed a correlation between the tin and lead content of the many ancient bronze coins uncovered during the excavations and their age and resulted in the publication in 1939 of his monograph, *The Composition of Ancient Greek Bronze Coins*, for which

he received the Lewis Prize from the American Philosophical Society in 1940 (40). This was followed in 1955 by his monograph, *Chemical Composition of Parthean Coins* (41).

Eventually at least 60 of Caley's more than 250 technical publications would deal with some aspect of archeological chemistry, including his 1956 translation (along with J. F. Richards) of the classic treatise, *On Stones*, by the Greek philosopher Theophrastus (42); his 1962 survey, *Analyses of Ancient Glasses, 1790-1957* (43); two more monographs on the analysis of ancient alloys and coins: *Orichalcum and Related Ancient Alloys* and *Analysis of Ancient Metals*, both of which were published in 1964 (44, 45); the 1965 booklet, *Metrological Tables*, dealing with ancient weights and measures (46); and, in retirement, his translation (along with J. S. Belkin) of those sections of the 1533 *Kreutterbüch* of Eucharius Rössln the Younger dealing with minerals and mineral products (47). In 1966 Caley was given the Dexter Award in the History of Chemistry by the Division of the History of Chemistry of the American Chemical Society in recognition of his outstanding contributions to the history of ancient chemical technology and chemical archeology.

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17. Summaries by von Lippmann of these early speculations may be found in E. O. Lippmann, "Über chemische Papyri des 3. Jahrhundertes n. Chr.," *Chem. Zeit.*, **1917**, *41*, 589-590 and E. O. Lippmann, "Zur Geschichte der Alchemie," *Angew. Chem.*, **1922**, 35, 529-531. Both are reprinted in reference 9, pp. 28-43. Later updates may be found in the various supplementary volumes to his *Entstehung und Ausbreitung der Alchemie*.

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29. J. B. Porta, *Natural Magick*, Young and Speed: London, 1658, Sections 5 and 6. Photo-reproduction published by Basic Books: New York, NY, 1957.

30. J. Bostock, H. T. Riley, *The Natural History of Pliny*, Vol. 6, Bohn: London, 1857, XXXVII, 76; XXXV, 150.

31. See Eamon (26), p. 31. This raises the further question of the prayer fragment found with the Stockholm papyrus and given the number 154 by Caley, as well as the various other magical papyri also found in the d'Anastasy collection. Here we need to remind ourselves that the papyri were freshly prepared burial copies intended accompany their deceased owner into the afterlife and that, in addition to the two chemical papyri, other, more specifically religious and magical materials, were without doubt also included in the burial, of which Recipe 154 is probably a fragment. Even if it is shown that the various gods invoked in the fragment and the other papyri are specially linked to the practice of the metallurgical and chemical arts, this would be unexceptional, since ancient craftsmen and artisans, as shown in several of the Assyrian cuneiform glass recipes, often sanctified their furnaces and other operations before undertaking the preparation of their various products.

32. A. J. Hopkins, "Bronzing Methods in the Alchemistic Leyden Papyrus," *Chem. News*, **1902**, *85*, 49-52, and A. J. Hopkins, *Alchemy Child of Greek Philosophy*, Columbia University Press: New York, NY, 1934.

33. R. Halleux, *Les alchimistes grecs. I. Papyrus de Leyde, Papyrus de Stockholm, Fragments de recettes*, Société d'édition "Les Belles Lettres": Paris, 1981.

34. The most recent evaluation of the chemical knowledge of the ancients that I am aware of is K. Volke, *Chemie in Altertum under besonderer Berücksichtung Mesopotamiens und der Mittelmeerländer*, Akademische Buchhandlung: Freiburg, 2009.

35. The most recent study is D. Helm, *Farben und Färben von Edelsteinen in der Antike*, Doctoral Dissertation, Frankfurt am Main, 1978. This has little to say on the modern replication of ancient recipes for the dying of crystals.

36. Modern examples of the surface dying of natural crystals are well known. However, most of these have involved synthetic coal-tar dyes and layered minerals, such as mica or various clays, though examples involving quartz have also been reported. For some lead-in references, see B. Kahr, R. W. Gurney, "Dying Crystals," *Chem. Rev.*, **2001**, *101*, 893-951.

37. The only suggestive reference to ancient examples of crystal dying I have encountered occurs in E. W. Lane, *An Account of the Manners and Customs of the Modern Egyptians*, Ward, Lock & Co: 1890, p. 231, where the author refers to the use of salt crystals dyed with indigo and other plant extracts in the superstitious rituals of early 19th-century Egyptians. This carries only the implication of more ancient origins and, in any case, involves growing the salt crystals in an aqueous solution of the dye, rather than the surface dying techniques described in the Stockholm papyrus. The resulting product is known as a dye inclusion crystal or DIC and is the primary focus of the review cited in reference 36. Since brine was often used as part of the recipes for dying wool given in the Stockholm papyrus, it is possible that examples of DIC salt crystals were first accidently discovered among the dye vat residues.

38. Biographical information based on A. J. Ihde, *A Quarter Century of the Dexter Awards*, Division of the History of Chemistry, American Chemical Society, 1981.

39. E. R. Caley, *The Metals and Their Compounds in Ancient Times*, M.S. Thesis, Ohio State University: Columus, OH, 1925.

40. E. R. Caley, *The Composition of Ancient Greek Coins*, American Philosophical Society: Philadelphia, PA, 1939.

41. E. R. Caley, *Chemical Composition of Parthean Coins*, American Numismatic Society: New York, NY, 1955.

42. E. R. Caley, J. F. Richards, *Theophrastus on Stones*, Ohio State University Press: Columbus, OH, 1956.

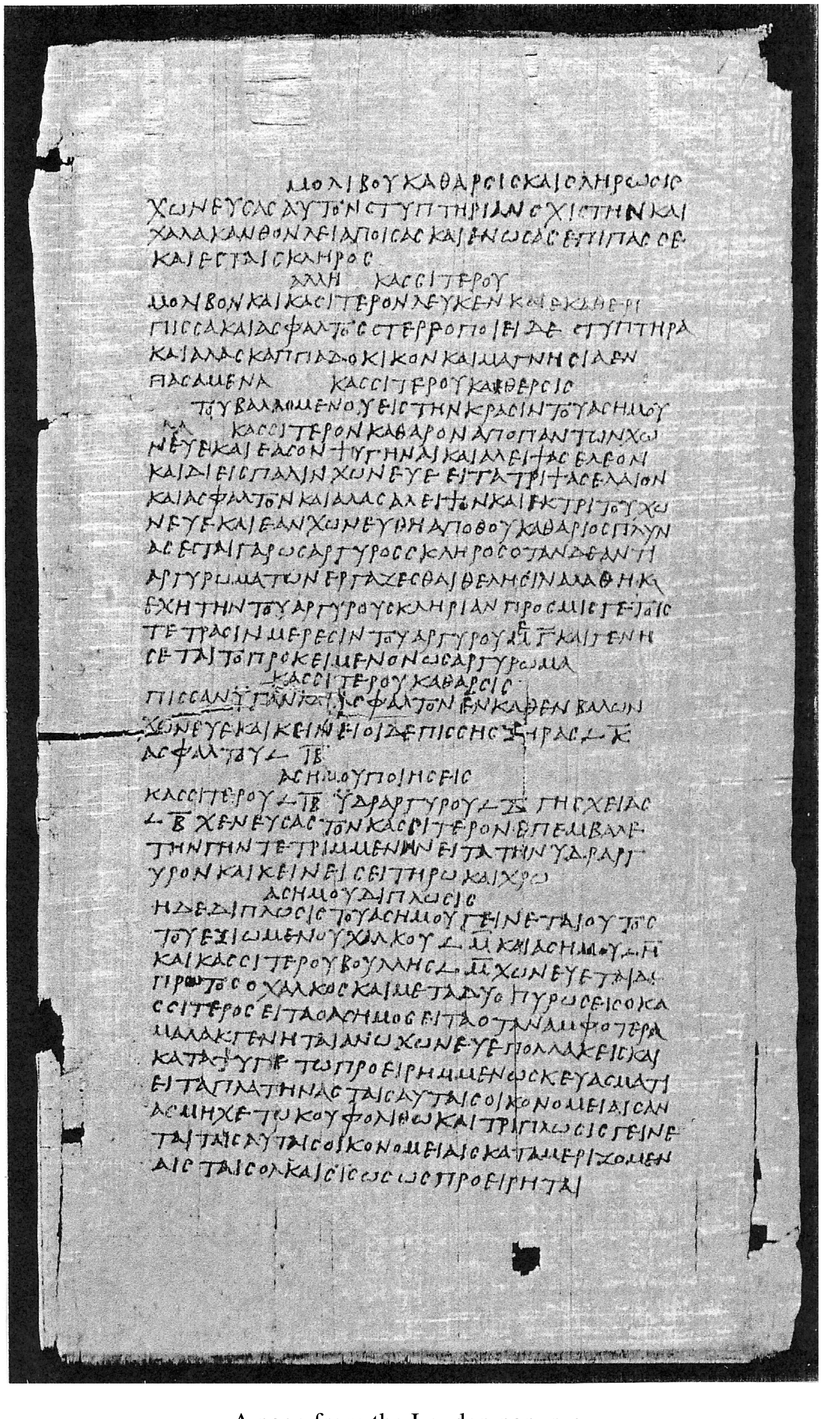
43. E. R. Caley, *Analyses of Ancient Glasses, 1790-1957, A Comprehensive and Critical Survey*, Corning Museum of Glass: Corning, NY, 1962.

44. E. R. Caley, *Orichalcum and Related Ancient Alloys: Origin, Composition and Manufacture with Special Reference to the Coinage of the Ancient Roman Empire*, American Numismatic Society: New York, NY, 1964.

45. E. R. Caley, *Analysis of Ancient Metals*, Pergamon: New York, NY, 1964.

46. E. R. Caley, *Metrological Tables*, American Numismatic Society: New York, NY, 1965.

47. E. R. Caley, J. S. Belkin, *Eucharius Rössln the Younger On Minerals and Mineral Products, Chapters from his Kreutterbüch,* de Gruyter: Berlin, 1978.



A page from the Leyden papyrus.

II
The Leyden Papyrus X

2.1 Description

The Leyden Papyrus X is in a remarkable state of preservation. It is formed of ten large leaves, each about thirty centimeters long and having a width of around thirty-four centimeters. It contains sixteen pages of writing, of from twenty-eight to forty-seven lines each, in Greek capital letters such as were in use during the third century A.D. It gives evidence of having been copied from still earlier documents and is full of grammatical errors and incorrect spellings (1, 2). It is written in the form of a recipe book and the recipes are often in an abbreviated, incomplete form such as workers, more or less familiar with the nature of the process, could use. The total number of recipes given is one hundred and eleven.

Seventy-five of these deal with methods for purifying metals, making alloys, testing metals for purity, imitating precious metals, and coloring the surfaces of metals and alloys. There are fifteen recipes on methods for writing in letters of gold and silver. Eleven recipes deal with methods of making dyes and dyeing cloth in purple and other colors. The last eleven recipes are simply short extracts from the *Materia medica* of Dioscorides Pedanius. They are chiefly descriptions of certain minerals. It is of interest to note that the extracts in the papyrus are very close to the present editions of this Greek writer compiled from quite different sources. No translation is given of these extracts since they are contained in published editions of the work of this author (3).

No English translation of the papyrus in its entirety has ever been published as far as the writer knows. A few recipes have been published previously by Stillman but these have been retranslated here in a more accurate manner (4). The author has based his translation upon the work of Leemans and upon the French translation of Berthelot (1). An endeavor has been made to give a close literal translation. Words in parentheses are lacking in the original, but are

thought necessary to give the proper meaning in the various places where used. Words and phrases needing special interpretation are discussed in the form of brief notes following each recipe. A more detailed discussion of the general chemical significance and value of the recipes will be given following the text of the translation.

2.2 Translation

1. Purification and Hardening of Lead

Melt it, spread on the surface lamellose alum and copperas reduced to a fine powder and mixed, and it will be hardened.

The word alum or rather "alumen" was employed by the ancient writers as a general term to signify a variety of products. Generally, they were impure mixtures of sulfates of iron and aluminum. This must have been widely used for purifying metals as the following recipes show.

2. Another (Purification) of Tin

Lead and white tin are also purified with pitch and bitumen. They are made pure by having alum, salt of Cappadocia, and stone of Magnesia thrown on their surfaces.

The ancient practice of naming chemical products and minerals according to the place of their origin is well shown in this recipe. The "salt of Cappadocia" probably was common salt while "stone of Magnesia" had various meanings but generally referred to magnetic iron oxide or to hematite.

3. Purification of Tin that is put into the Alloy of Asem

Take tin purified of any other substance, melt it, let it cool; after having well mixed and covered it with oil, melt it again; then having crushed together some oil, some bitumen, and some salt, rub it on the metal and melt a third lime; after fusion, break apart the tin after having purified it by washing: for it will be like hard

silver. Then if you wish to employ it in the manufacture of silver objects, of such a kind that they cannot be found out and which have the hardness of silver, blend 4 parts of silver and 3 parts of tin and the product will become as a silver object.

The word “asem” or “asemon” was employed for alloys intended to imitate gold or silver, most generally the latter.

4. Purification of Tin

Liquid pitch and bitumen, a part of each; throw (them on the tin), melt, stir. Dry pitch, 20 drachmas; bitumen, 12 drachmas.

5. Manufacture of Asem

Tin, 12 drachmas; mercury, 4 drachmas; earth of Chios, 2 drachmas. To the melted tin, add the crushed earth, then the mercury, stir with an iron, and put (the product) in use.

The “earth of Chios” mentioned here was a kind of clay.

6. The Doubling of Asem

One takes: refined copper, 40 drachmas; asem, 8 drachmas; tin in buttons, 40 drachmas: one first melts the copper and after two heatings, the tin; then the asem. When all are softened, remelt several times and cool by means of the preceding composition. After having augmented the metal by these proceedings, clean it with talc. The tripling is affected by the same procedure, with weight being proportioned in conformity with what has been stated above.

The preceding composition referred to in this recipe is apparently recipe No. 5.

7. Inexhaustible Stock

It is prepared by the procedures described in the doubling of asem. If you wish to deduct 8 drachmas from the stock, separate them and remelt with 4 drachmas of this same asem; melt these three times and then repeat, then cool and place in reserve in the talc.

8. Manufacture of Asem

Take soft tin in small pieces, purified four times; take 4 parts of it and 3 parts of pure white copper and 1 part of asem. Melt, and after the casting, clean several times and make with it whatever you wish to. It will be asem of the first quality, which will deceive even the artisans.

The term, "white copper," refers to a particular copper alloy. A single word "Aes" was applied by the Ancients to both pure copper and its alloys.

9. Manufacture of Fusible Asem

Copper of Cyprus 1 mina; tin in sticks, 1 mina; stone of Magnesia, 16 drachmas; mercury, 8 drachmas, stone of Paros, 20 drachmas. Having melted the copper, throw the tin on it, then the stone of Magnesia in powdered form, then the stone of Paros, and finally the mercury; stir with an iron rod and pour at the desired time.

The island of Cyprus was an important source of copper in ancient times and the metal from this source was considered then to be of superior quality. "Stone of Paros" is mentioned by Pliny as being a white, hard stone similar to the marble from this place.

10. Doubling of Asem

Take refined copper of Cyprus, throw upon it equal parts, that is, 4 drachmas of salt of Ammon and 4 drachmas of alum; melt and add equal parts of asem.

11. Manufacture of Asem

Purify lead carefully with pitch and bitumen, or tin as well; and mix cadmia and litharge in equal parts with the lead, and stir until the alloy is completed and solidifies. It can be used like natural asem.

The word “cadmia” was applied to condensed fumes and smoke gathered from the interior of copper and brass smelters and hence was often a complex mixture of metallic oxides. In a special sense it meant zinc oxide. “Natural asem” was the naturally occurring alloy of gold and silver known as electrum.

12. Manufacture of Asem

Take some shreds of (metallic) leaves, dip in vinegar and white lamellose alum and let them soak during seven days, and then melt with a fourth part of copper, 8 drachmas of earth of Chios, 8 drachmas of asemian earth, 1 drachma of salt of Cappadocia (and) additional lamellous alum, 1 drachma; mix, melt, and cast the black (refuse) from the surface.

The nature of the metal first used is not stated. The chemical nature of the “asemian earth” is also unknown to us,

13. Manufacture of an Alloy

Copper from Galacia, 8 drachmas; tin in sticks, 12 drachmas; stone of Magnesia, 6 drachmas; mercury, 10 drachmas; asem, 5 drachmas.

14. Manufacture of an Alloy for a Preparation

Copper, 1 mina, melt and throw on it 1 mina of tin in buttons and use thus.

15. The Coloration of Gold

To color gold to render it fit for usage. Misy, salt, and vinegar accruing from the purification of gold; mix it all and throw in the vessel (which contains it) the gold described in the preceding preparation; let it remain some time, (and then) having drawn (the gold) from the vessel, heat it upon the coals; then again throw it in the vessel which contains the above-mentioned preparation; do this several times until it becomes fit for use.

According to Pliny the "misy" of the Ancients was either iron or copper pyrites or oxidation products of these, that is, basic iron or copper sulfates or various mixtures of these salts. (See Pliny, *Natural History*, Book XXXIV, Chap. 31)

16. Augmentation of Gold

To augment gold, take cadmia of Thracia, make the mixture with cadmia in crusts, or that from Galacia.

This is apparently the beginning of a longer recipe. No. 17 seems to be the remainder of it. Berthelot has suggested that the title of No. 17 was a comment or gloss erroneously added to the papyrus by a copyist.

17. Falsification of Gold

Misy and Sinopian red, equal parts to one part of gold. After the gold has been thrown in the furnace and it has become of good color, throw upon it these two ingredients, and removing (the gold) let it cool and the gold is doubled.

The meaning of "sinopian red" is various. The description of Dioscorides, *Materia medica*, V, 3) would make it appear that it was an iron ochre, although it sometimes referred to red lead.

18. Manufacture of Asem

Tin, a tenth of a mina; copper of Cyprus, a sixteenth of a mina; mineral of Magnesia, a thirty-second; mercury, two staters. Melt the copper, throw on it at first, the tin, then the stone of Magnesia; then having melted these materials, add to them an eighth (part) of good white asem of a suitable nature. Then, when the alloying has taken place and at the lime of cooling, or of remelting together, add then the mercury last of all.

19. Another (Formula)

Copper of Cyprus, 4 staters; earth of Samos, 4 staters; lamellose alum, 4 staters; common salt, 2 staters; blackened asem, 2 staters, or if you desire to make it more beautiful, 4 staters. Having melted the copper, spread upon it the earth of Samos and the lamellose alum crushed together, stir in such a way as to mix them; and having melted this asem, pour. Having mixed that which has just been melted with some (wood of) juniper, burn it; before setting aside after having healed it, extinguish the product in lamellose alum and salt taken in equal parts, with some slimy water slightly thick; and if you wish to finish the work immerse again in the above-mentioned; heat so (the metal) becomes white. Take care to employ refined copper beforehand, having heated it at the beginning and submitted it to the action of the bellows, until this has rejected its scale and become pure; and then use it as has has been stated.

20. Another (Formula)

Take a Ptolemaic Stater, for they contain copper in their composition, and immerse it; now the composition of the liquid for the immersion is this: lamellose alum, common salt, in vinegar for immersing; (make of) slimy thickness. After having immersed and at the moment when the melted metal has been cleaned with this composition, heat, then immerse, then take out, then heat.

20. (An Additional Part Without a Title)

Here is the composition of the liquid for immersing: lamellose alum, common salt, in the vinegar for immersing; (make of) slimy thickness; having immersed in this mixture, heat, then immerse, then lake out, then heat; when you have immersed four times or more, by previous heating each time, the (metal) will become superior to blackened asem. The more numerous the treatments, heatings, and immersions are, the more it will improve.

21. Treatment of Hard Asem

How it is expedient to proceed to change black and hard asem into white and soft (metal). Taking some leaves of the castor-oil plant, infuse them a day in water; then soak it in the water before melting and melt twice and sprinkle with aphronitron. And throw alum on the casting; put into use. It possesses quality for it is beautiful.

The word "aphronitron" was applied to a variety of saline efflorescences especially from dry or arid regions. Most probably it was a natural alkali which was essentially sodium carbonate.

22. Another (Formula)

A remedy for all tarnished asem. Taking straw, barley, and wild rue, infuse in vinegar, pour on it some salt and coals; throw it all in the furnace, blow for a long while and let cool.

23. Whitening of Copper

For whitening copper, in order to mix it with with parts of asem, so that no one can recognize it. Taking some Cyprian copper, melt it, throwing on it 1 mina of decomposed sandarach, 2 drachmas of sandarach of the color of iron, and 5 drachmas of lamellose alum and melt (again). In the second melting, there is thrown on 4 drachmas, or less, of wax of Pontus: it is heated and then poured.

"Sandarach" was the term used to denote the native arsenic sulfide

that is today known as realgar by the mineralogists. "Decomposed sandarach" possibly referred to that subjected to a roasting process and would in reality be the oxide.

24. Hardening of Tin

For hardening tin, spread separately (on its surface) lamellose alum and copperas; if, moreover, you have purified the tin as is necessary and have employed the materials previously named, in such a way that they did not escape by flowing away during the heating, you have Egyptian asem for the manufacture of objects (of jewelry).

25. Gold Polish

For treating gold, otherwise called, purifying gold and rendering it brilliant: Misy, 4 parts; alum, 4 parts; salt, 4 parts. Pulverize with water. And having coated the gold (with it), place it in an earthenware vessel deposited in a furnace and luted with clay, (and heat) until the above-named substances have become molten, then withdraw it and scour carefully.

26. Purification of Silver

How silver is purified and made brilliant. Take a part of silver and an equal weight of lead: place in a furnace and keep up the melting until the lead has just been consumed; repeat the operation several times until it becomes brilliant.

27. Coloring in Silver

For silvering objects of copper: tin in sticks, 2 drachmas; mercury, 2 drachmas; earth of Chios, 2 drachmas. Melt the tin, throw on the crushed earth, then the mercury, and stir with an iron and fashion into globules.

28. Manufacture of Copper Similar to Gold

Crush some cumin; pour on it some water, dilute, and let it remain in contact during three days. On the fourth day shake, and if you wish to use it as a coating mix chrysocolla with it; and the gold will appear.

The word "chrysocolla" referred to salts of copper and to a gold alloy used for soldering gold. In the above recipe, which is evidently a varnish, the latter was probably used in a pulverized form.

29. Manufacture of Fusible Asem

Copper of Cyprus, 1 part; tin, 1 part; stone of Magnesia, 1 part; raw stone of Paros powdered finely. One melts the copper first, then the tin and then stone of Magnesia; then next, one throws the powdered stone of Paros upon this; the stirring is done with an iron and the operation is performed in a crucible.

30. Manufacture of Asem

Tin, a measure; copper of Galacia, a half measure. Melt at first the copper, then the tin, stir with an iron, and throw on it dry pitch, until it is saturated; immediately pour, remelt, employing lamellose alum in the same manner as the pitch, and then pour (again). If you wish to melt the tin first, then the copper in filings after, follow the same proportions in the same manner.

31. Preparation of Chrysocollia

Solder for gold is thus: copper of Cyprus, 4 parts; asem, 2 parts; gold, 1 part. The copper is first melted, then the asem, and finally the gold.

32. To Recognize the Purity of Tin

After having melted, place some papyrus below it and pour; if the papyrus bums, the tin contains some lead.

33. Manufacture of Solder for Working Gold

How one goes about making the solder for works of gold: Gold, 2 parts: Copper, 1 part; melt (and) divide up. When you desire a brilliant color melt with a little silver.

34. A Procedure for Writing in Letters of Gold

To write in letters of gold, take some mercury, pour it in a suitable vessel, and add to it some gold in leaves; when the gold appears dissolved in the mercury, agitate sharply; add a little gum, 1 grain for example, and, (after) letting stand, write in the letters of gold.

35. Another (Recipe)

Golden-colored litharge, 1 part; alum, 2 parts.

36. Manufacture of Asem that is Black like Obsidian

Asem, 2 parts, lead, 4 parts. Place in an earthen vessel, throw on it a triple weight of unburnt sulfur, and having placed it in the furnace, melt. And having withdrawn it from the furnace, beat, and make what you wish. If you wish to make figured objects in beaten or cast metal, then polish and cut. It will not rust.

37. Manufacture of Asem

Good tin, 1 part; add to it, dry pitch, one quarter of the weight of the tin; having stirred, let the pitch froth until it has been completely ejected; then, having let the tin solidify, remelt it and add 13 drachmas of tin (and) 1 drachma of mercury, (then) stir up; let cool and work just like asem.

38. For Giving to Objects of Copper the Appearance of Gold

And neither touch nor rubbing against the touchstone will detect them, but they can serve especially for (the manufacturing of) a

ring of fine appearance. Here is the preparation for this. Gold and lead are ground to a fine powder like flour, 2 parts of lead for 1 of gold, then having mixed, they are incorporated with gum, and one coats the ring with this mixture; then it is heated. One repeats this several times until the object has taken the color. It is difficult to detect (the fraud), because rubbing gives the mark of a gold object, and the heat consumes the lead but not the gold.

39. Writing in Letters of Gold

Letters of gold: saffron (and) bile of a river tortoise.

40. Manufacture of Asem

Take white tin, finely divided, (and) purify it four times; then take 4 parts of it, and a fourth part of pure white copper and 1 part of asem (and) melt: when the mixture has been melted, sprinkle it with the greatest possible quantity of salt, and make what you wish with it, either by hammering or by any way you please. The metal will be equal to true asem, so much so as to deceive even the artisans.

41. Another (Procedure)

Silver, 2 parts; purified tin, 3 parts; cooper, (?) drachmas; melt, then remove and clean; put in use for works of silver the best kind.

42. Coating of Copper

If you desire that the copper shall have the appearance of silver; after having purified the copper with care, place it in mercury and white lead; mercury alone suffices for coating it.

43. Testing of Gold

If you wish to test the purity of gold, remelt it and heat it: if it is pure it will keep its color after heating and remain like a piece of money. If it becomes white, it contains silver; if it becomes rougher and harder, some copper and tin; if it blackens and softens, lead.

44. Testing of Silver

Heat the silver or melt it, as with gold; and if it remains white (and) brilliant, it is pure and not false; if it appears black, it contains some lead; if it appears hard and yellow, it contains some copper.

45. Writing in Leaves of Gold

To write in letters of gold. write what you desire with goldsmith's solder and vinegar.

46. Cleaning of Copper Objects

Having boiled some beets, carefully clean the objects of copper and silver with the juice. The beets are boiled in water.

47. Copper Equal to Gold

Copper equal to gold in color, as follows: grind some cumin in water; let it set carefully during three days; on the fourth, having wet (it) abundantly, coat the copper (with it) and write whatever you wish. For the coating and the writing have the same appearance.

48. Cleaning of Silver Objects

Clean with sheep's wool, after having dipped in sharp brine; then clean with sweet water and put into use.

49. Gilding of Silver

For gilding a vase of silver or copper without leaves (of gold), dissolve some yellow natron and some salt in water, rub it with this and it will be (gilded).

The chemical nature of "yellow natron" is not known with certainty. From certain passages in Pliny and other writers it would appear that this was a sodium sulfide made by fusing sulfur and native

sodium carbonate together. In this case the metal would not be gilded but would at least be colored by the above recipe.

50. Writing in Letters of Gold

Grind arsenic with gum, then with some well water; in the third place write.

The word "arsenic" in this recipe refers to the native yellow arsenic sulfide.

51. Gilding of Silver

Grind misy with sandarach and cinnabar and rub the object with it.

53. Writing in Letters of Gold

After having dried the gold leaves, grind with gum and write.

54. Preparation of Liquid Gold

Place some leaves of gold in a mortar, grind them with some mercury and it is done.

55. Coloration in Gold

How one should prepare gilded silver. Mix some cinnabar with alum, pour some white vinegar upon this, and having brought it all to the consistency of wax, press out several times and let it stand over night.

56. Preparation of Gold

Asem, 1 stater, or Copper of Cyprus, 3; 4 staters of gold; melt together.

57. Another Preparation

To gild silver in a durable fashion. Take some mercury some leaves

of gold, and make up into the consistency of wax; taking the vessel of silver, clean it with alum, and taking a little of the waxy material, lay it on with the polisher and let the material fasten itself on. Do this five times. Hold the vessel with a genuine linen cloth in order not to soil it. Then taking some embers, prepare some ashes (and with them) smooth (it) with the polisher and use as a gold vessel. It can be submitted to the test for regular gold.

58. Writing in Letters of Gold

Golden-colored arsenic, 20 drachmas; pulverized glass, 4 staters; of white of egg, 2 staters; white gum, 20 staters; saffron .... after having written, let dry and polish with a tooth.

59. Manufacture of Asem

Asem is also prepared with copper; (silver) 2 mina; tin in grains, 1 mina; melting first the copper, throw on it the tin and some talc called chalk, a half to one mina; proceed until you see the silver and the chalk melt; after which the remainder will have been dissipated and only the silver will remain, then let it cool, and use it as asem preferable to the genuine.

The chemical nature of the mineral or flux called “talc” or “chalk” in this recipe is unknown. Certainly it does not correspond to the substances of that name that we are acquainted with.

60. Another (Preparation)

Everlasting asem is prepared thus: 1 slater of good asem; add to it 2 staters of refined copper, melt two or three times.

61. Whitening of Tin

To whiten tin. Having heated (it) with alum and natron, melt.

62. Writing in Letters of Asem.

Dilute some copperas and some sulfur with vinegar; write with the thickened material.

63. Writing in Letters of Gold

Flower of cencos, white gum, white of egg mixed in a shell, and incorporate with bile of tortoise, by estimation as one does for colors; put into use. The very bitter bile of a calf also serves for the color.

The plant mentioned here was evidently one containing yellow coloring matter although its exact species is not known.

64. Testing of Asem

To recognize if asem is false. Place it in brine (and) heat; if it is false, it will blacken.

65. Cleaning of Tin

Place some gypsum on a rag and scour.

66. Cleaning of Silver

Employ moist alum.

67. Coloring of Asem

Cinnabar, 1 part; lamellous alum, 1 part; Cimolian earth, 1 part; moisten with sea salt and put into use.

68. Softening of Copper

Heat it; place it in bird dung and, after cooling, take out.

69. Coloring of Gold

Roasted misy, 3 parts; lamellose alum, (and) celandine, about 1 part; grind to the consistency of honey with the urine of a small child and color the object; heat and immerse in cold water.

70. Writing in Letters of Gold

Take a quarter portion of tested gold, melt in a goldsmith's crucible; when it has become molten add a carat of lead; after it has become alloyed, set it aside, cool and take a mortar of jasper, throw in it the melted material; add 1 carat of natron and carefully mix the powder with some strong vinegar, in the same manner as for an eye-salve medicine, for three days; then when the mixture is completed, incorporate 1 carat of lamellose alum, write and polish with a tooth.

71. Writing in Letters of Gold

Soft leaves of Gold; pulverize with mercury in a mortar; and employ them in writing, after the manner of black ink.

72. Another (Preparation)

Incombustible sulfur .... , Lamellose alum .... , gum .... , sprinkle the gum with water.

73. Another (Preparation)

Unburnt sulfur .... , lamellose alum, a drachma; add a medium quantity of dry rust; pulverize the rust, the sulfur, and the alum finely; mix properly; grind it with care and employ it for writing in the same way as black ink by diluting it with some wine free from sea water. Write upon papyrus or parchment.

74. Another (Preparation)

To write in letters of gold, without gold. Celandine, 1 part; pure

resin, 1 part; golden-colored arsenic, of the fragile kind, 1 part; pure gum; bile of tortoise, 1 part; the liquid part of eggs, 5 parts; take 20 staters by weight of all these materials dried; then throw in 4 staters of saffron of Cilicia. Can be used not only on papyrus or parchment, but also upon highly polished marble, or as well when you wish to make a beautiful design upon some other object and give it the appearance of gold.

75. Gilding

Gilding gives the same effect. Lamellose arsenic, copperas, golden sandarach, mercury, gum tragacanth, pith of arum, equal parts; dilute the whole with the bile of a goat. It is applied upon copper objects, upon silver objects, upon figures (in metal) and upon small shields. The copper should not have a rough surface.

The terms "lamellose arsenic" and "golden sandarach" in the above recipe undoubtedly referred to varieties of the native sulfides of arsenic that we term as realgar and orpiment. Pliny and Dioscorides both describe these minerals in their writings.

76. Another (Procedure)

Misy from the mines, 3 staters; alum from the mines, 3 staters; celandine, 1 stater; pour on these the urine of a small child; grind together until the mixture becomes viscous and immerse (the object in it).

77. Another (Procedure)

Take some cumin, crush it (and) let it infuse three days in water, on the fourth take out; coat the objects of copper with it, or whatever you wish. It is necessary to keep the vessel closed during the three days.

78. Writing in Letters of Gold

Grind some gold leaves with gum, dry and use like black ink.

79. Writing in Letters of Silver

To write in letters of silver. Litharge, 4 staters; dilute with the dung of a pigeon and some vinegar; write with a stylus passed through the fire.

80. Coloring of Asem

Cinnabar, Cimolian earth (and) liquid alum, equal parts; mix with sea water, heat and dampen several times.

81. Coloration in Silver

Such that it can only be removed by fire. Chrysocolla, ceruse, earth of Chios and mercury ground together; add some honey and having first treated the vessel with natron, coat (the vessel) with it.

"Ceruse" or "cerussa" was the ancient term for white lead, which was well-known and widely employed as a cosmetic by the Greeks and Romans.

82. Hardening of Tin

Melt it, add to it a homogeneous mixture of lamellose alum and copperas; pulverize and sprinkle (over the metal) and it will be hard.

83. Manufacture of Asem

Good tin, 1 mina; dry pitch, 13 staters; bitumin, 8 staters; melt in a vessel of baked earth luted around (the top); after having cooled, mix 10 staters of copper in round grains and 3 staters of asem first (and then) 12 staters of broken stone of Magenesia. Melt and make what you wish.

84. Manufacture of Egyptian Asem

Recipe of Phimenas (or Pammenes). Take some soft copper of

Cyprus, purify it with some vinegar, some salt and some alum; after having purified it, melt 10 staters of the copper, throwing on it 3 staters of well-purified ceruse, 2 staters of golden-colored litharge, after which it will become white. Then add to it 2 staters of very soft asem without blemish and the product will be obtained. Take care in melting that it does not liquate. This is not the work of an ignorant person, but of an experienced man, and the union of the two metals will be good.

85. Another (Procedure)

An exact preparation of asem, preferable to that of asem properly so-called. Take: orichalcum, 1 drachma, for example; place in a crucible until it melts; throw upon it 4 drachmas of salt of Ammon or Cappadocian salt; remelt, add to it lamellose alum (in an amount equal to) the weight of an Egyptian bean; remelt, add to it 1 drachma of decomposed sandarach, not the golden sandarach but that which whitens; then transfer to another crucible previously coated with earth of Chios; after fusion add a fourth part of asem and put into use.

"Orichalcum" or "aurichalcum," as it was sometimes spelled, was an alloy consisting mainly of copper and zinc – in other words what we term today as brass. The term "decomposed sandarach" in the above would seem to indicate that the native arsenic sulfides were sometimes roasted and the resulting product, which would be essentially arsenious oxide, was then used in making alloys.

86. Another (Procedure)

Take: tin, 12 drachmas; mercury, 4 drachmas; earth of Chios, 2 drachmas; melt the tin, throw upon it the earth in powder, (and) then the mercury; stir with a bar of iron; fashion into globules.

87. Doubling of Gold

For augmenting the weight of gold. Melt (it) with a fourth part of cadmia, and it will become heavier and harder.

88. Another (Procedure)

Gold can be altered and increased by means of misy and earth of Sinopus. One first casts it in the furnace with equal parts (of them). When it has become clear in the crucible, one adds each as it is desired, and the gold is doubled.

89. Another (Preparation)

The invention of sulfur water. A handful of lime and another of sulfur in fine powder; place them in a vessel containing strong vinegar or the urine of a small child. Heat it from below, until the supernatant liquid appears like blood. Decant this latter properly in order to separate it from the deposit, and use.

90. How Asem is Diluted

Having reduced the asem into leaves and having covered it with mercury and applied (it) strongly upon the leaf, one sprinkles pyrites upon the leaf thus prepared, and places it upon the coals, in order to dry it up to the point when the color of the leaf appears changed; for the mercury evaporates and the leaf softens. Then one incorporates in the crucible 1 part of gold, (and) 2 parts of silver. Having blended them, throw upon the floating scum some golden-colored arsenic, some pyrites, some salt of Ammon, some chalcitis, (and) some blue; and having ground with sulfur water, heat, then spread mercury upon the surface.

In the above recipe appears for the first time, in written form, evidence of symbolism in chemical arts, both gold and silver being designated by special characters. The word “chalcilis” was used in ancient times to designate copper minerals, especially, according to Pliny's descriptions, copper pyrites. The unknown blue substance hinted at in the above was also most probably a copper salt or mineral [*Editor’s note:* This may be the same as the Armenian blue referred to in the Stockholm papyrus].

91. The Fixation of Alkanet

Urine of sheep, or arbute-berry, or henbane in the same manner.

92. Falsification of Alkanet

Alkanet is diluted with pine-cones, the inside part of peaches, purpura, beet juice, dregs of wine, the urine of a camel and the interior of citrons.

93. Fixation of Alkanet

Navelwort and alum mixed in equal parts, crush finely (and) throw the alkanet in it.

94. Styptic Agents

Melantheria, calcined copperas, alum, chalcitis, cinnabar, lime, bark of pomegranate, pod of a thorny tree, urine with aloes. These things serve in dyeing.

"Melantheria" was a word applied to the products of the weathering of copper ores at the surface of mine shafts. Usually these ores were sulfides and the product then must have been chiefly basic iron and copper sulfate.

95. The Preparation of Purple

Break into small pieces stone of Phrygia; put it to boiling, and having immersed the wool, leave it until it cools. Then throwing in the vessel a mina of seaweed, put it to boiling and throw in it (again) a mina of seaweed. Let it boil and throw the wool into it, and letting it cool, wash with sea water ... [the stone of Phrygia is roasted before being broken] ... until the purple coloration appears.

The "stone of Phrygia" was evidently some kind of a mordant and may have been, as Berthelot suggested, a type of alunite. The seaweed mentioned above was probably the so-called dyers moss or archil.

96. Dyeing with Purple (Two Methods)

Grind lime with water and let it stand over night. Having decanted, deposit the wool in the liquid for a day; take it out (and) dry it; having sprinkled the alkanet with some vinegar. Put it to boiling and throw the wool in it and it will come out dyed in purple .... alkanet boiled with water and natron produces the purple color. Then dry the wool and dye it as follows: Boil the seaweed with water and when it has been exhausted, throw in the water an imperceptible quantity of copperas, in order to develop the purple, and then plunge the wool in it, and it will be dyed. If there is too much copperas, it becomes darker.

97. Another (Procedure)

Grind some walnuts with some alkanet of good quality. This done, place them in some strong vinegar; grind again; add some pomegranate bark to this; lay aside three days; and after this, plunge the wool in it and it will be dyed cold .... It is said that there is a certain acanthus which furnishes the purple color; moistened with some natron of Berenice in place of nuts, it produces the same effect.

98. Another (Procedure)

Clean the wool with fullers plant, and hold at your disposal some lamellose alum. (Then) grinding the interior part of gall-nut, throw it in a pot with the alum, then put in the wool and let it remain several hours. Take it out and let it dry. Follow this procedure first: Having ground the lees (from wine) and having placed them in a vessel, pour in sea water, agitate and set aside. Then decant the clear water into another vessel and hold it at your disposal. Taking the alkanet and placing it in a vessel, mix with the water from the lees until it thickens conveniently and becomes as though sandy. Then place the product in a vessel, diluting it by estimation with the preceding water which comes from the alkanet. Then, when it has become as though slimy, place it in a small kettle, add to it the remainder of the alkanet water, and leave until lukewarm. Then

plunge the wool in it, lay aside several hours, and you will find the purple fast.

99. Another (Process)

Taking alkanet, (and) some leontice, strip off the bark, take it and grind it as fine as stibnite in a mortar. Add to it some hydromel diluted with water, grind again, place the ground product in a vessel and boil. When you observe (the liquid) to be lukewarm, plunge the wool in it (and) let it remain. The wool ought to be cleaned with fullers plant and thickened. Then take it, plunge it in lime water; let it soak; take it out; wash thoroughly with some sea salt (and) dry. Plunge it again in the alkanet and let it remain.

100. Another (Procedure)

Take the juice of the upper part of the alkanet and a solid gall-nut roasted in the oven. Having ground it with the addition of a little copperas, mix with the juice, boil, and make the purple dye.

101. A Substitute for Greenish-Blue Color

In place of greenish-blue color, take scoria of iron, crush it with care until reduced to the appearance of smegma, and boil it with some vinegar until it becomes stiff. Immerse the wool previously cleaned with heavy fullers herb, and you will find it dyed in purple. Dye in this way with the colors that you have.

Iron oxide or scales from the forging of iron was called "scoria of iron," while the term "smegma" was applied to copper oxide made by blowing across the surface of molten copper with bellows.

102. Arsenic

103. Sandarach

104. Misy

105. Cadmia

106. Chrysocolla

107. Rubric of Sinopia

108. Alum

109. Natron

110. Cinnabar

111. Mercury

As mentioned in the introduction, the last recipes in the papyrus are sections extracted from the well-known *Materia medica* of Dioscorides. They are chiefly descriptive of certain minerals and metallurgical products used in antiquity. The title only of each recipe is given here since their contents have been widely published in the many editions of this writer's works (3).

2.3 Commentary

By reason of the antiquity and character of the papyrus there is much in it of great interest to historians and philologists, but no attempt will be made here to comment upon this phase of the subject. Its significance and meaning from the chemical standpoint will be chiefly stressed in as concise a way as possible; emphasis being placed upon its general nature rather than upon a detailed examination of each of its recipes and preparations.

Perhaps one of the most striking points to be noticed about the collection is the numerous repetitions in the nature of the recipes, many of them only varying slightly in the proportions of the same ingredients. This doubtless indicates that it was collected from various sources and from pre-existing documents now lost to us. Furthermore, this fact pushes still farther back the time when the chemical arts and operations described in the papyrus must have been known to mankind. To be remarked also is the fragmentary

character of many of the recipes, and the essential omissions in many of them giving the impression that they were rather in the nature of reminders for skilled workers rather than detailed descriptions for purposes of general information. This fact emphasizes the likelihood that this papyrus was a kind of a laboratory notebook of the operations of the chemical arts of the times.

The recipes dealing with metals and alloys are certainly the most numerous. These may be conveniently grouped as follows: The making of alloys, coloring the surfaces of metals, cleaning and purifying metals, and testing metals for purity. The first of these, the manufacture of alloys, is the subject of the majority of the recipes. And, in nearly all cases the alloy being made is the same one – namely, "asem." The word itself referred either to silver, alloys of silver and gold, or in fact to any alloy used in jewelry resembling these. As a matter of fact, the whole viewpoint of the ancients regarding substances was so entirely different from ours that we sometimes forget that they generally failed to distinguish metals, chemically, from each other very clearly and went wholly upon appearances. For example, if two alloys had the same appearance although differing in composition they considered them identical. This is checked further in other cases, notably among the Romans, who applied the same name "aes" to all kinds of copper alloys regardless of composition.

In the papyrus most of the recipes are simply straightforward working directions, although in one or two cases there is direct evidence of an intention to deceive. Thus in No. 8 we read, "this will be asem of the first quality, which will deceive even the artisans," showing that there was some recognition of chemical differences aside from qualitative appearances. Perhaps the workers of the recipes knew this, but it is certain that this knowledge was not general, as the philosophy of the ancients so well informs us. It is these practical recipes and working directions for making alloys from various metals that later became fused with various mystical and philosophical doctrines and so grew into alchemy. Hence, the papyrus is of the highest historical importance chemically in showing the real starting point of the alchemical ideas of the transmutation of metals.

As to the practical composition of the alloys themselves, they

are seen to vary from simple two-metal combinations to those containing four or five metals. The metals used were gold, silver, tin, copper, lead, mercury, arsenic, antimony, and zinc, the latter ones being used in the form of their compounds and not being distinguished in the metallic state. A curious fad to be noted in the making of these alloys is that in nearly all cases where compounds are employed there is no mention of a reducing agent being employed. Perhaps the furnaces used were operated under reducing conditions or it was understood by the workers that charcoal or wood was to be placed with the metals being fused. The limited range in the type of alloys whose manufacture is described indicates that the owner or owners of the papyrus were chiefly interested in making ornamental jewelry and not in practical metals such as bronze and steel. At any rate the recipes for alloys in this papyrus are the earliest detailed quantitative directions for alloy manufacture that we have knowledge of. Other ancient writers such as Pliny and Dioscorides who touch upon technical subjects are singularly lacking in details, indicating their lack of direct knowledge, but the papyrus here considered is certainly a direct laboratory document and hence its importance for the history of chemistry.

Next in importance to the making of the alloys themselves come the recipes that deal with refining, cleaning, coloring, and otherwise treating metals. The second recipe in the papyrus is an example of the purification of metals by adding reducing agents to the molten metals, pitch and oils being used for this purpose. Another method of purification that was evidently in use in ancient times was the addition of various chemical salts to fused metals and alloys to serve as fluxes and solvents for the impurities. Alum, iron sulfate, crude soda ash, and common salt were most commonly employed for this purpose. Several recipes are given for cleaning and polishing the surface of cold metals. The softening and hardening of metals was also quite well-known then as several of the recipes show, and this is borne out by the fact that the hardening of steel by tempering was a familiar operation in Roman times. A curious sidelight on the impurity of the crude metals then employed is shown by the fact that recipes for hardening lead are

in reality only those for removing excessive impurities, an indication that the crude metal was mixed with quantities of oxides.

The coloring of metals superficially was evidently widely practiced. Mercury was applied to alloys and base metals to give a silvery appearance as well as being incorporated in the alloys themselves. A curious method of gilding with gold is given in Recipe No. 38 in which a mixture of powdered gold and lead are fastened upon an object with the subsequent burning off of the base metal. The use of gold amalgam in gilding silver is also fully explained in No. 57. Besides using metals for coloring metallic surfaces they also employed various colored varnishes and dyes as several of the recipes of the papyrus indicate. Recipe No. 89 is especially interesting from the chemical point of view as being evidently a preparation of a solution of sulfides of calcium, the original lime-sulfur mixture. This is the only actual preparation of a chemical salt listed in the collection. Probably this was used to color the surfaces of metals also.

The crude methods of testing gold and silver for purity employed in those times are well described in Recipes No. 43 and 44. The discoloration of the metals by the formation of metallic oxides was depended upon to indicate fraud. No doubt this was sufficiently accurate to indicate gross adulterations, but it certainly could not satisfy us in these days. The fact that metals had different melting points was well-recognized and used, as Recipe No. 32 on testing tin shows. Pliny also describes this method in Book XXXIV of his *Natural History*. This method would indeed distinguish between tin and lead. but eutectic mixtures must certainly have deceived some of the workers of those days. This crude method of determining temperatures is truly indicative of the elementary state of chemical arts at the opening of the Christian era.

Writing and making inscriptions in metallic letters or in characters colored so as to resemble gold and silver must also have been an important operation for the workers of that period if the number of the recipes in the papyrus bearing upon the subject are to be taken as a true indication. Gold amalgam is used for the purpose in several recipes. A point worthy of note about these is that no mention is made of heating the finished writing to drive off the excess mercury. No doubt this was understood by the workers or transmit-

ted by word of mouth. This fact well indicates the fragmentary and incomplete character of the procedures described. Litharge, sulfur, and various organic pigments and colors were also incorporated with gum water and other mediums to yield colored writing.

The last recipes in the papyrus deal with methods of dyeing cloths. Various vegetable substances were applied to this purpose. There is direct and indisputable evidence that the necessity and practice of mordanting cloth previous to dyeing it was well-understood. The fact that the recipes are usually those for dyeing in purple shows that this papyrus was probably used in connection with royal or priestly workshops since the nobility were the only ones then generally permitted to wear purple. These recipes also expose the common fallacy that the ancient peoples only obtained their purple from the shellfish murex. They evidently used other dyes to a larger extent. The fact that the dyeing of cloths is so little touched upon in the Leyden Papyrus X and was of such importance in ancient chemical arts leads us to believe that the papyrus gives us only a partial view of the state of ancient chemical art. The Stockholm Papyrus is really volume II of the set for in it very little space is given over to metallic arts while much space is devoted to dyeing cloths, imitating precious stones, and other operations not even mentioned in the Leyden Papyrus. The recent finds of numerous papyri in Egypt may also bring to light those of technical importance and enrich our knowledge of the early period of chemical history, although there is a certain degree of improbability about this since it is a known historical fact that books on alchemical processes and technical arts were systematically destroyed in Egypt during the first centuries of the Christian era.

2.4 References

1. *C. Leemans, Papyri graeci musei antiquarii publici Lugduni-Batavi*, Vol. 2, Brill: Leiden, 1885.

2. M. Berthelot, *Introduction a l'étude de la chimie des anciens et du moyen age*, Steinheil: Paris, 1889.

3. Such as *Des Pedanios Dioskorides .... in fünf Buchern*, Translated by J. Berendes, Stuttgart, 1902.

4. J. M. Stillman, *The Story of Early Chemistry*, Appleton: New York, 1924. Chap. II.



A page from the Stockholm papyrus showing a recipe for the preparation of imitation emeralds. The margins have been trimmed at the top and bottom by the photographer

III
The Stockholm Papyrus

3.1 Description

The Stockholm Papyrus is formed of fifteen loose papyrus leaves measuring about thirty centimeters in length and about sixteen centimeters in width. These correspond very nearly in size with the double sheets of the Leyden Papyrus X. Like the Leyden Papyrus it is in an excellent state of preservation. There are from forty-one to forty-seven closely written lines of Greek capital letters on each page. The pages are numbered consecutively although the separate recipes are not. It is purely and simply a collection of recipes like the Leyden Papyrus with but few traces of any theoretical considerations. There are numerous duplications, abbreviations, and omissions in these recipes as though, as was probably the case, they were simply intended as reminders to those already skilled in the practice of the arts they deal with. A total of one hundred fifty-four recipes is contained in the papyrus. Only nine of these deal with metals. There are some seventy recipes treating of the art of imitating precious stones and of improving the appearance of genuine ones. The remaining recipes deal chiefly with the mordanting and dyeing of cloth. The last one is of quite a different character than the remainder and its significance will be discussed in the brief commentary following the translation.

The translation which now follows is based upon both the Greek text and the German translation of Lagercrantz (1). An endeavor has been made to give a faithful English version as far as possible although the exact nature of some of the substances mentioned in the papyrus is difficult to determine with accuracy. For these cases and for others where a little explanation is deemed necessary, brief notes follow the recipe containing them. Words in parentheses are lacking in the original but are added to give a true meaning in English where it has been thought necessary. For purposes of greater convenience in referring to them the trans-

lator has taken the liberty of numbering the recipes consecutively although in neither the original nor in the German translations of Lagercrantz was this done. A few short comments upon the chemical aspects and the general technical significance of the recipes will follow the translation.

3.2 Translation

1. Manufacture of Silver

Plunge Cyprian copper, which is well worked and shingled for use, into dyer's vinegar and alum and let soak for three days. Then for every mina of copper mix in 6 drachmas each of, earth of Chios, salt of Cappadocia and lamellose alum, and cast. Cast skillfully, however, and it will prove to be regular silver. Place in it not more than 20 drachmas of good, unfalsified, proof silver, which the whole mixture retains and (this) will make it imperishable.

Many of the substances used in ancient times were named according to their place of origin rather than from their chemical nature. This is well shown in this recipe. The island of Cyprus was a famous source of copper in ancient times. The term alum or "alumen" referred to a variety of natural products which were usually impure mixtures of iron and aluminum sulfates put up in various forms. The "earth of Chios" was probably a kind of a clay, while "salt of Cappadocia" was our common salt, from a chemical point of view.

2. Another (Recipe)

Anaxilaus traces back to Democritus also the following recipe. He rubbed common salt together with lamellose alum in vinegar and formed very fine small cones from these and let them dry for three days in the bath chamber. Then he ground them small, cast copper together with them three times and cooled, quenching in sea water. Whatever comes out will show a purification.

3. Another (Recipe)

Purify white tin four times and melt together 6 parts of this and 1 mina of white Galatian copper; rub off and make what you wish. It will be silver of the first quality, except that the artisans can notice something (peculiar) about it because it is formed by the procedure mentioned.

4. Purification of Tin

The purification of tin, which enters into the alloy with silver, is done in the following way. Let pure tin cool, coat if with oil and bitumen, and melt it four times. Lay it aside after washing in a clean manner. Alloy 6 parts of this and 7 parts of Galatian copper with 4 parts of silver and it will be regarded as wrought silver.

5. Doubling of Silver

It is done by different procedures. Melt Cyprian copper, which is purified with "coral," six times and add silver for the purpose of doubling.

6. Another (Recipe)

Dip clippings from small copper plates into brine and let them soak six days in alum and brilliant earth which have been previously dissolved in fresh water. Melt it afterwards and gradually alloy silver with it.

The exact nature of the shining or brilliant earth mentioned in this recipe and the following one is impossible to determine.

7. Another (Recipe)

In addition to these recipes (is) also the following. Galatian copper 1/2 part, silver, and ordinary tin, which the western Iberians among whom it is produced call bulla just as the Romans do. The copper

is first melted, then the silver, and after two heatings, the tin. Then when the whole has become soft, remelt it many times and cool with brilliant earth, held in readiness, which is previously dissolved in spring water. Take out and quench the resulting lumps, heat them again, and indeed many limes, until very white silver comes from them. Remove them and shingle, rub and polish with talc, and work up the silver thus doubled. And tripling is done in the same way with the above-mentioned distribution of weights.

8. (No Title)

On the other hand, an inexhaustible mass can be prepared from the foregoing recipe for doubling. Take off 8 drachmas from the lump, mix just as many drachmas of silver with the lump, and remelt it at the same time. Do this three times, cool, and set away in talc.

9. Manufacture of Silver

Buy charcoal which the smiths use and soften it in vinegar one day. After that, take 1 ounce of copper, soak it thoroughly in alum, and melt it. After that, take 8 ounces of mercury but pour out the mercury thus measured into a secretion of poppy juice. Take also 1 ounce of silver. Put these materials together and melt; and when you have melted them, put the lumps so formed in a copper vessel with the urine of a pregnant animal and iron filing dust (for) 3 days. And the singular cloudiness which you will get on taking out is a sign of the natural fluctuation by which the mixture finds itself of equal composition by weight.

10. Whitening of Pearls

To make brownish pearls white when this is due to smoke. Take about 1 obulus of honey which is unadulterated and add to it 2 cups of cistern water. Make honey water out of this and pour it in a small jar. Bruise fig root small and put it in. If it pops while you are cooking it remove away from the fire and calm it with the liquor. After you have made it really soft, and have stirred and measured it with the nail, smear the pearls with it and let it harden. Wipe it off

with a pure linen rag and the pearls will at once show their whiteness. If they do not yet appear to you to have become entirely white, coat them anew, for the more you coat them and wipe them off the whiter they become. However, when it is cooked, do not cook it again, but use it all at once (and) at the same time.

11. Another (Recipe)

Take the pieces of mother of pearl or the pearls and put them into bitch's milk. Put the cover upon the vessel and leave it there 2 days and 2 nights. Draw them out, as they lie there strung on asses' hair, and observe whether they have become white. If not, put them in again until they become excellent in this respect. If you afterwards besmear a man with this he becomes leprous.

12. Another (Recipe)

By the following procedure one likewise makes papyrus sheets, which are written upon, clean again so that they appear as though they never had been written upon. Take and dissolve natron in water. Then put in, when the soda solution has formed, 1 part of raw earth, 1 part of Cimolian earth, and cow's milk in addition so that all of it comes to a glutinous mixture. Then mix in oil of mastic and daub it on with a feather. Let it dry and then scale it off and you will find the pearls white. If they are a deep yellow, daub it on again. If dealing with a papyrus sheet, only coat the characters.

The "nitron" of the Greeks referred to the natural deposits of alkaline salts from various sources. The uses to which it was put shows it to have been essentially sodium carbonate so that the term natron as used here is not thought inappropriate as an inclusive term for all such alkaline deposits. "Cimolian earth" was perhaps a kind of a clay.

13. Another (Recipe)

First take and etch the pearls in the urine of an uncorrupted youth;

coat them with alum, and let dry on them what remains of the corrosive. This take and put mercury and fresh bitch's milk into a clay vessel, heat all together and in doing so regulate what takes place. Use only foreign coals and a gentle fire.

14. Preparation of Carnelian

Dissolve alkanet in oil. After that, put in the blood of a pigeon, and fine Sinopian earth and a little vinegar in order that the blood does not coagulate. Place selenite in it, close the vessel and place it amidst the dew for ten days. If you wish to make the stone very brilliant, arrange it so as to wrap it in horse hair, tie this on, and put it in the dye bath.

It is not certain whether what we term as "selenite" was used here, but at any rate it was some kind of a transparent stone capable of absorbing color, and it appears very probable that our selenite was used.

15. Preparation of Lapis Lazuli

The lapis lazuli employed is first dipped in the bile of a tortoise and then placed in the dye bath for amethyst for just as many days as for this and so forth.

16. Purification of Crystal

The purification of a smoky crystal. Put it in a willow basket, place the basket in the boiler of the bath and leave the crystal there 7 days. Take it out when it is purified, and mix warm lime with vinegar. Stick the stone therein and let it be etched. Finally, color it as you wish.

17. Preparation of Emerald

Take and put so-called topaz stone in liquid alum and leave it there 3 days. Then remove it from this and put it in a small copper vessel in which you have placed pure unadulterated verdigris along with

sharp vinegar. Put the cover upon the vessel, close up the cover, and gently keep afire under the vessel with olive wood for 6 hours, otherwise the longer you maintain the fire, the better and deeper will the stone be – only, as I say, with a gentle fire. Cool and lift the stone out. Its condition will show whether it has become emerald. That is to say, you will observe that a green film has formed upon it. Let it become slowly cooled, however; if not, it soon breaks. Put oil in a small box-tree vessel many days beforehand so that the oil is purified and the product from it can be taken off. Put in the stone and leave it under cover 7 days. On taking out you will have an emerald which resembles the natural ones.

18. Manufacture of a Pearl

Take and grind an easily pulverized stone such as window mica. Take gum tragacanth and let it soften for ten days in cow's milk. When it has become soft, dissolve it until it becomes as thick as glue. Melt Tyrian wax; add to this, in addition, the white of egg. The mercury should amount to 2 parts and the stone, 1 parts, but all remaining substances 1 part apiece. Mix (the ground mica and the molten wax) and knead the mixture with mercury. Soften the paste in the gum solution and the contents of the hen's egg. Mix all of the liquids in this way with the paste. Then make the pearl that you intend to, according to a pattern. The paste very shortly turns to stone. Make deep round impressions and bore through it while it is moist. Let the pearl thus solidify and polish it highly. If managed properly, it will excel the natural.

19. Production of Ruby

The treating of crystal so that it appears like ruby. Take smoky crystal and make the ordinary stone from it. Take and heat it gradually in the dark; and indeed until it appears to you to have the heat within it. Heat it once more in gold-founder's waste. Take and dip the stone in cedar oil mixed with natural sulphur and leave it in the dye, for the purpose of absorption, until morning.

20. Preparation of Green Stone

Take and work crystal – (that) with the surname, chimney (crystal) – weighing not more than two drachmas, into ordinary stones. Take and grind Macedonian verdigris and the leaves of winter-berry to suitable fineness. Dissolve the rubbings in sharp vinegar and heat the vessel with a gentle fire until the stones become green. These stones also should hang in a basket so that one can take them out and see whether they have become green. If not, put them in again until they become so.

21. Another (Recipe)

Verdigris and vinegar, verdigris and oil, verdigris and calves' bile; these form emerald.

22. Preparation of a Pearl

Etch crystal in urine and alum for several days. Take and boil together over a gentle fire with the crystals the juice of the scarlet pimpernel, which bears blue flowers, of houseleek, and of spurge; and besides the juices, mercury in addition.

23. Preparation of a Pearl

Etch crystal in the urine of an uncorrupted youth and round alum; then dip it in mercury and woman's milk.

24. Corroding of Stones

A corrosive for any stone. Equal amounts of alum and natron are boiled in an equal amount of water. The small stones are then etched. Previously warm them slightly near the fire and dip them in the corrosive. Do this for a while once to three times while the corrosive boils; dip and leave again three times but no more, so that the small stones do not break.

25. Whitening of a Pearl

A dark pearl is made white by the following method. Give it to a cock to swallow, cut him open immediately, and you will find that the pearl has become white.

26. Corrosion of Sunstone

A corroding of sunstone which boils it at the same time. Boil together seeds of mezereon and vinegar with the stone until a third of the fluid remains behind.

27. Opening Up of Stones

Make sure that the stones are receptive; and that the dense stone is loosened up. Place it in a soft fig, lay upon the coals, and the stone will immediately change.

28. Preservation of Crystal

In order that small stones which are prepared from crystal do not break into pieces, take and open a fig, put the stone therein, and lay the fig upon the coals to roast.

29. Corroding of Stones

Let urine and alum putrify and remain together with the stones for 30 days. Then take the stones out and stick them in soft figs or dates. These stones should also be worked on the coats. Therefore, blow with the bellows until the figs or the dates burn and become charcoal. Then seize the stone, not with the hand but with the tongs, and put it directly into the dye bath while still warm, and let it cool there. Make as many stones as you wish of, however, not more than 2 drachmas (each in weight). The dye bath should, however, be like paste.

30. Preparation of Emerald

To prepare emerald from crystal. Take a clay vessel, mix in it round alum with water, and put it aside. Take transparent wax of equal weight with the crystal – of this latter not more than 2 drachmas can be transformed – melt, and put it aside in a vessel. Take the crystal and put it in the alum a day and a night. In this way it becomes, of course, bluish. Then take it out and coat it with the wax. Then take the crystal out of the wax and put it in verdigris, but have the 1 ounce of verdigris pulverized, and boil the crystal for 6 hours in a small vessel containing 6 cups. Then place it in the verdigris a day and a night. Take it out on the next day.

31. Boiling of Stones

If you wish to make ruby from crystal, which is worked to any desired end, take and put it in the pan and stir up turpentine balsam and a little pulverized alkanet there until the dye liquid rises; and then take care of the stone.

32. Preparation of Emerald

Unadulterated verdigris, copper green, bile of tortoise (and) of steers 2 parts, smoky crystal.

33. Preservation of Crystal

So that it neither splits nor breaks. Take and mix the whole of a goose's egg with talc. Make it of pasty thickness and smear the crystal with it. Then put it in linen, bind this around it and leave 3 days in the dew and the sunshine. Untie after the three days and work the stone.

34. Preparation of Emerald

Boil for 1 hour. 1 part of roasted copper, 2 parts of verdigris, (and) as much Pontic honey as is needed.

35. Another (Preparation)

Take rainbow-colored Indian crystal, shape from it the small stones that you desire, and soften them. Afterwards, take equal weights of flaky alum and "garlic" and rub them fine with very sharp vinegar until the whole becomes paste-like in thickness. Put the small stones in it and leave them there 3 days. After this, pour vinegar upon the mixture so that it becomes fluid, pour it over into a foreign pot, hang the stones there in a basket so that they do not touch the bottom of the vessel, and gently boil upon the coals. However, the pot should be provided with a cover and be coated with tallow. Blow with the bellows so that the fire does not become extinguished. Heat for two hours. Then take equal parts of both Macedonian copper green and verdigris and 1/2 a part of the bile of a calf and grind all extremely fine. Then pour thereupon the oil from unripe olives, measuring with the eye. Then take wax, rub the stones over with it, and leave them with the oil alone, or with castor oil besides, which you place in the small pot. Again hang the stones in a basket and heat for 6 hours. Rehang the stones once more on a horse hair and let them remain in the mixture over night. Then take them out and you will find that they have changed to emeralds.

The true meaning of the term "garlic" is explained in recipe No. 51. This is an excellent example of the use of veiled terms and hidden meanings, a practice which was common among the early workers.

36. Softening of Crystal

To soften crystal take goat's blood and dip crystal, which you have previously heated over a gentle fire, into it until it suits you.

37. Softening of Emerald

Stick hard emerald into wax for 14 days. After this period, grate "garlic" and make a cake out of it. Take the stone out (of the wax)

and stick it into the cake of "garlic" for 7 days. Take leek and extract the juice out of it. Mix until the leek juice an equal amount of oil, put this in a new pot, put the stones in it at the same time and boil 3 days (or) until they become satisfactory to you. The stones should be in a basket so that they do not touch the bottom of the pot.

38. General Preliminary Corrosion

The plant heliotrope along with its blossom serves for the corrosion of every stone; for opening up, agglomeration and corroding. For without this plant, which the stones absorb, neither crystal nor the so-called topas, that is carried down from Egypt, can be opened up. Apply also the juice of the plant for the preliminary corrosion and you will have luck with the coloring.

39. Preparation of Beryl

Take rock crystal, string it on a hair, and hang it in a jar with the urine of a she-ass in such a manner that the stone does not touch the urine. The jar should be closed 3 days. After this lapse of time place the jar over a gentle fire and you will find an excellent beryl.

40. Special Corrosion of Crystal

Dissolve sulphur, quicklime, (and) alum in vinegar. Do this three or four times, let it absorb the solution for 3 or 4 days, and then use in the following recipe.

41. Preliminary Dipping

Dip the stones beforehand in this: salt 1 part, water 1/10 part. The stones (are) to be previously plunged in this material. Warm them again, after they are dried, over the opening of the oven. Then make out of the stones what you desire.

42. Preparation of Emerald

Mix 1 part of roasted copper (and) 2 parts of verdigris with honey and place it upon the ashes. Let it cook and place the crystal in it.

43. Another (Preparation)

Mix l/2 a drachma of copper green, an equal quantity of Armenian blue, 1/2 a cup of the urine of an uncorrupted youth, two-thirds of the fluid of a steer's gall, and put into it the stones weighing 1/12 of a drachma each. Place the cover upon the vessel, lute the cover with clay, and heat for 6 hours with a gentle fire of hard olive wood. However provided that this sign appears – (namely) that the cover becomes green – then heat no further but let the stones cool down, lift them out and you will find that they have become emeralds. The stones are of crystal. If crystal is boiled in castor oil it becomes black.

Armenian blue was probably some kind of a copper mineral or an oxidation product of the same.

44. Preparation of Amethyst

Corrode the stones beforehand with three times as much alum as stone. Cook them in it until it boils thrice, and let them cool down. Take and soften krimnos with vinegar. Then take and boil the stones in it as long as you like.

The substance "krimnos" is frequently mentioned in these recipes. It was evidently a red dyestuff, but its exact source and nature is unknown to us.

45. Preparation of Chrysolite

Heat crystal, dip it in liquid pitch and cedar oil, and it will thence become chrysolite.

46. Preparation of Lychnis

Corrode the stones beforehand as set forth above. In this manner take archil, alkanet, and vinegar and place the stone therein as long as desired.

According to Pliny (*Natural History,* XXXVII, 103) this stone was red in color like the ruby.

47. Preparation of Beryl

Mix Indian black with resin and heat crystal. If you let it cool in the mixture then excellent beryl comes forth from it.

48. Another (Preparation)

Make a solution from the bile of a tortoise together with the milk. of a pregnant animal, copper, and sharp vinegar; and in this solution beryl will come into existence from stone. Only the experts can discover (the fraud).

49. Preparation of Jasper

Heat the stone, then corrode it in alum along with vinegar and put it in verdigris and calves' gall.

50. Preparation of Sunstone

Boil liquid pitch and alkanet, put the stone in it and it will thence become sunstone; or in the juice of mulberries, or in ground kermes with vinegar; or in Armenian blue with calves' gall.

51. Corrosion of Crystal

Before one puts it in for coloring. Grind 1 part of quicklime and 1 part of natural sulphur. Add vinegar and put the stones in it. And in the third place it states thus; human excrement is, as they say, garlic.

This latter sentence, which appears to have no connection with the remainder of the recipe, is apparently a reference to some other work. It is of value in showing the use of cryptic words and secret meanings.

52. Preparation of Sunstone

Take equal parts of sulphur, vinegar, and calves' gall. First-class, flawless sunstone is turned out with this mixture.

53. Corroding and Opening Up of Stones

Grind alum and melt it carefully in vinegar. Put the stones therein, boil it up. and leave them there over night. Rinse them off, however, on the following day and color them as you wish by use of the recipes for coloring.

54. Another (Recipe)

Put the stones in a dish, lay another dish on it as a cover, lute the joint with clay, and let the stones be roasted for a time under supervision. Then remove the cover gradually and pour alum and vinegar upon the stones. Then afterward color the stones with the dye as you wish.

55. Corrosion of Crystal

Crystal, which undergoes uninterrupted corrosion a day and a night, becomes bluish.

56. Bleaching of Crystal

Dissolve rice in water, put the crystal in, and again boil the solution with it.

57. Softening of Crystal

Soften crystal by cooking in goat's blood. The same recipe also applies to glass.

58. Preparation of Sunstone

First etch smoky stone in alum and water for 7 days, then heat it gradually and put it in cedar oil with the tongs.

59. Substitute for Castor Oil

All crystal becomes dark by boiling in castor oil. On that account do not use the substance where it states "with castor oil," for the material is to be substituted. Use olive oil instead of castor oil.

60. Cleaning of a Pearl

When perchance a genuine pearl becomes faded and dirty through use the Indians are accustomed to cleaning it in the following manner. They give the pearl to a rooster as food in the evening. In the morning they search for it again in the excretion and ascertain that the pearl has become clean in the crop of the bird; and, moreover, has acquired a whiteness which is not inferior to the former.

61. Another (Recipe)

Quicklime, which if not yet slaked in water after burning in the oven, curiously carries over the imperceptible (and) transmissible fire. They dissolve (it) in dog's milk – from a white she-dog however. They then knead the lime and rub it around about the pearl and leave it 1 day in this manner. After they have wiped off the lime, they find out that the pearl has become white.

62. Preparation of Sunstone

Mix dragon's blood, ordinary sap of balsam tree, resin of Palestine

– or if that is not at hand (resin) of Tomi – and Pontic alkanet; and soak the opened-up crystal therein. Now, if the preparation is unmixed, sunstone comes forth. If, however, a little fluid pitch is mixed with the above mixture, then ruby is likely to result.

63. Preparation of Beryl

Crystal has a considerable relationship with beryl on the basis of resemblance and you will get beryl out of crystal if you open up this stone, cool down after heating, and put it inside the forenamed resin and the indigo mixed with it. If it is put inside the preparation (while) still hot, then colored hyacinth is formed from it.

64. Preparation of Chrysoprase

If celandine is mixed with indigo a green color results. Take, however, resin besides – it is a suitable substance for dyeing – put the crystal in this mixture after the opening up of it, leave it to absorb therefrom and chrysoprase stone comes forth.

65. Preparation of Chrysolite

Chrysolite results when you heat crystal and put it in fluid pitch and celandine mixed.

66. Corrosion of Stones

The corroding of stones should be done in about the following manner. Put the stones in open clay pans and lay covers upon them. Close them with clay and place them upon the grate. Then gradually take the covers off and dip the stones in alum soaked in vinegar. Then heat them again and put them in the dyes made lukewarm.

67. Another (Recipe)

Finally in another way. Put the stones in a pan, lay thereupon

another pan as a cover, and heat them gradually. Then gently take the cover off and pour alum along with vinegar over the stones. Color them with the color that you desire.

68. Corrosion of Crystal

A special corrosion of crystal. It is put in sulphur, quicklime, and alum together with vinegar, three or four times. However, leave it to absorb therefrom 3 or 4 days and then apply the following recipe.

69. Corrosion of All Kinds of Stones

The plant heliotrope, which produces clusters, serves for the general opening up and corrosion of every stone. Extract the juice from it, open up the stones therein, and you will have good luck with the coloring of every stone.

70. The Kinds of Stones to Color

The suitable stones for coloring are crystal and topaz. Pyrites has the tendency to become gradually red. Boil (the stones), however, whilst you exclude everything, in a small protected house which stands opposite to any adverse wind.

The pyrites mentioned here is certainly not the mineral that we call by that name. Great uncertainty exists as to just what the Ancients did mean by their term pyrites. Compare Pliny, Book XXXVII, 189, and Book XXXVI, 137, with Dioscorides V, 84, to see the confusion concerning this word.

71. Preparation of Emerald

Mix copper green, the urine of a boy, and calves' bile in a new pot. Lute the cover with clay, but previously put the crystals in the pot, and cook it for 5 hours with a gentle fire of olive wood. You wilt suddenly see by the cover when it is to be heated no more. Cool and take them out. The cover of the pot should, however, be unbaked.

72. Another (Preparation)

Preparation for another rough emerald. Stick the stone in natron for 5 days. Then stick it in a lump of ground "garlic" for 7 days. But after the lapse of this time draw the juice from a leek and mix along with it an equal quantity of oil. Put this in a new pot and boil it 3 days until the stones absorb it. The cover should be unbaked.

73. Another (Recipe)

Rub with vinegar: 1 part of very fine verdigris; an equal amount of alum; roasted copper, a quantity equal to both the other materials; and bring it to a pasty thickness. Put the small stones therein and let them be baked for 7 days.

74. Preparation of Verdigris for Emerald

Clean a well-made sheet of Cyprian copper by means of pumice stone and water, dry, and smear it very lightly with a very little oil. Spread it out and tie a cord around it. Then hang it in cask with sharp vinegar so that it does not touch the vinegar, and carefully close the cask so that no evaporation takes place. Now if you put it in in the morning, then scrape off the verdigris carefully in the evening, but if you put it in in the evening, then scrape it off in the morning, and suspend it again until the sheet becomes used up. However, as often as you scrape it off again, smear the sheet with oil as explained previously. The vinegar is (thus rendered) unfit for use.

75. Preparation of Beryl

Tie crystal around with a hair and hang it in a pot along with the urine of a she-ass for 3 days, but the crystal is not permitted to touch the urine. The pot should be closed, however. Then place the pot over a gentle fire and you will find a very good beryl.

76. Preparation of Emerald

Take pure pyrites or rock crystal and make the composition in the following way: Verdigris, 2 drachmas; celandine, 1 drachma; Scythian black, 3 drachmas; liquid resin, which one holds in the mouth, as much as necessary. Pulverize the dry materials, mix the resin with them, and set it aside. Take liquid alum, pour water upon it so that it becomes very watery and preserve it in a clay vessel. Heat the stone in an earthen vessel and cool it off in the alum. Heat the stone and put it in the above-named composition. However, if you desire that it should be greener then again mix pulverized verdigris with it.

The chemical nature of Scythian black is unknown.

77. Another (Recipe)

Grind scraped-off verdigris and soften in oil a day and a night. Boil the stones therein with a gentle flame as long as desired.

78. Preparation of Emerald

Dissolve alum with vinegar in an earthen vessel and set it aside. Take crystal and leave it therein a day and a night. Then take it and coat it with wax or clay. After that, cook it in oil. If, however, the stone is hard, hang it in honey. Then lift it out and put it in copper green a day and a night. Take it out and cover it so that no evaporation occurs. After that, smear it again with the materials until it becomes emerald.

79. Preparation of Emerald

Mix: copper green, 9 drachmas; celandine, 1 drachma; verdigris, 1 drachma; indigo, 3 oboli; (and) resin. Coat the stones with this mixture.

80. The Dissolving of Comarum

Take and put lye from ashes upon comarum. Place it upon the fire a night and a day and it will become dissolved. The lye from ashes is, however, according to the following preparation. Place ashes in sufficient water and put this in a pot. Make a cavity and put quicklime in the hole. Pour in it the lye from the ashes and it will flow pure through the palm flower wrapping. Apply this material for dissolving.

The substance called "comarum" was used as a mordant in coloring stones and cloth. Its exact nature is not known.

81. Another (Recipe)

Several have also undertaken the dissolving with this, namely "capnelaion," which is a very dear substance; others again with the sap of balsam trees.

82. Another (Recipe)

The dissolving of comarum. Put in a pot about two pints of spring water. When this has been boiled once, put in the pot a third of gum tragacanth and a third of cleaned and washed comarum which you have finely pulverized. However, when this has boiled six times take it away from the fire – but boil with a gentle fire. Place it again upon the ground, let it cool off for several days and use it thus. The solution of comarum is also useful as a preliminary coating for every stone.

83. Preparation of Emerald

Mix and put together in a small jar 1/2 a drachma of copper green, 1/2 a drachma of Armenian blue, 1/2 a cup of the urine of an uncorrupted youth, and two-thirds of the fluid of a steer's gall. Put entire stones therin, indeed (about) 24 pieces, so that they weigh about 1/2 an obolus. Lay the cover upon the pot, lute the cover all

around with clay, and boil it with a gentle fire for six hours, at which olive wood is to be burned. But if this sign appears, namely, that the cover becomes green, then heat no more, but cool off and take the stones out. Thus you will find that they have become emeralds. The stones are of crystal. All crystal, however, changes its color by boiling.

84. A Dye Liquor for Three Colors

A dye liquor from which three dye solutions can come. Bruise and mix with water, 2/3 of a part of Krimnos and 1 part of dyer's alum. Put the wool in and it becomes scarlet red. If it is to be leek green, add ground sulphur with water. If, however, it is to be quince yellow, then add unadulterated natron along with water.

85. Cleaning with Soap Weed

Cleaning with soap weed is done in the following way. Take and bruise soap weed, put it in water and heat it. Then put the wool in and shake it a little. Lift out and dry it. Then mordant it afterwards.

86. For Purple

Boil asphodel and natron, put the wool in it 8 drachmas at a time, and rinse it out. Then take and bruise 1 mina of grape skins, mix these with vinegar and let stand 6 hours. Then boil the mixture and put the wool in.

87. Mordanting

Boil chalcanthum and skorpiurus aim employ for any desired color. These substances, however, also mordant all kinds of stones and skins.

The term "chalcanthum" was used to denote various products of the weathering of iron and copper pyrites and hence was either copper or iron sulfate or mixtures of these salts. The Greek word

"skorpiurus" was, according to some, a name given to one of a species of sapindaceous plants.

88. The Dissolving of Alkanet

Alkanet is dissolved by oil, water, and nuts. The best of all dissolving mediums is, however, camel's urine. For this makes the alkanet dye not only fast, but also durable.

89. Another (Recipe)

Bruise alkanet and mix natron with it until it gets blood-colored. The boiling is done with water. Then dye what you desire. Or else bruise alkanet in the same way with safflower, afterwards put it in and let the blood color be absorbed. And if you bruise alkanet with telis then proceed likewise. Alkanet in company with chalcanthum, however, dyes linen as well as cambric. For with chalcanthum, alkanet red changes into purple.

"Telis" is a certain species of a plant or flower.

90. Making Purple Brilliant

To make purple brilliant cook alkanet with purging weed and this will dissolve it; or with wild cucumber, purgative cucumber or hellebore.

91. The Dissolving of Alkanet

Take alkanet and grind fine with barley malt. The barley malt should, however, be fresh. Then mix the alkanet with vinegar and let it remain in it over night. Heat the alkanet again in the morning, steep it in vinegar and leave it until it gives up the color. After that take the wool and put it in lime water and then in the dye liquor. After you have then put it in an extract of archil, treat it then in the same way as has been explained in detail in passage 26.

This latter sentence is apparently a reference to another work or collection of recipes now lost to us.

92. The Dissolving of Comarum

To dissolve comarum. Grind tartar with water, put it in a small dish and stir it. Pour the clear water in another vessel. put ground comarum in it, stir it and it will give up its color at once. Then let it clarify until the following day and you will find purple.

93. Mordanting for Sardian Purple

For a mina of wool put in 4 minas of dross of iron (and) 1 choenix of sour pomegranate; but if not this (latter) then (use) 1 chus of vinegar (and) 8 chus of water (heated) over the fire until half of the water has disappeared. Then take the fire away from under it, put the cleaned wool in and leave it there until the water becomes cold. Then take it out, rinse it and it will be mordanted.

94. Mordanting for Silician Purple

Put in the kettle 8 chus of water, a half a mina of alum, 1 mina of flowers of copper (and) 1 mina of gall-nuts. When it boils, put in 1 mina of washed wool. When it has boiled two or three times take the wool out. For when you leave it therein a longer time then the purple becomes red. Take the wool out, however, rinse it out and you will have it mordanted.

In ancient times, and among the alchemists, the term "flowers of copper" referred to copper oxide.

95. Mordanting and Dyeing of Genuine Purple

For a stater of wool put in a vessel 5 oboli of alum (and) 2 kotyles of water. Boil and let it (become) lukewarm. Leave it until early morning, then take it off and cool it. Then prepare a secondary mordant (in which) you put 8 drachmas of pomegranate blossoms and two kotyks of water in a vessel. Let it boil and put the wool in.

However, after you have dipped the wool in several times, lift it out. Add to the pomegranate blossom water about a ball of alumed archil and dye the wool by judging with the eye. If you wish, however, that the purple be dark, add a little chalcanthum and let the wool remain long in it. In another passage it is in the following way: But if you wish that the purple be dark, then sprinkle natron and a little chalcanthum in the dye bath.

96. Dyeing in Purple

Purple. Roast and boil Phrygian stone. Leave the wool therein until it becomes cold. Then lift it out, put 1 mina (each) of archil and amaranth in another vessel, boil then and lei the wool cool down in it.

Phrygian stone was evidently some kind of a mineral capable of yielding soluble salts. It may have been a type of alunite according to Berthelot. This would explain its use in mordanting.

97. Another (Recipe)

Take the wool and clean with soap weed. Take blood stone and put it in a kettle. Put therein previously boiled chalcanthum. Put in the wool previously mordanted in urine, alum, and misy. Lift the wool out, rinse it with salt water, let it become cold, and brighten the purple with gall-nut and hyacinthe. It has a very beautiful foreign appearance.

“Bloodstone” is identical with our hematite while “misy” was either iron or copper pyrites or oxidation products of these (see Pliny, *Natural History*, Book XXXIV, 31). “Hyacinthe” was some kind of a vegetable dyeing material.

98. Another (Recipe)

Take and boil grain weevils, dross of iron and laurel berries. Put in 2 minas of wool, which you have previously mordanted, and now

have boiled. Take it out and let it cool off. Brighten the color with limewater.

99. Another (Recipe)

Phrygian stone is roasted and boiled. The wool is put in and left there until it becomes cold. Then lift it out, place in another vessel 1 part of archil and 1 part of amaranth blossoms, boil it again, put the wool in mid let it become cold there. Lift it out and rinse it with salt water.

100. Another (Recipe)

To dye with mulberries. Take and crush unripe bunches of grapes and mordant the wool therein for 3 days. On the fourth day put this grape juice in another pot and boil the wool therein, but when it boils lift it out, rinse it with water and let it become cold. Then take juice of mulberries and boil up until it boils twice. Put the wool in and let it become cold therein and it will be a fine excellent purple.

101. Cold Dyeing of Purple Which Is Done in the True Way

Keep this as a secret matter because the purple has an extremely beautiful luster. Take scum of woad from the dyer, and a sufficient portion of foreign alkanet of about the same weight as the scum – the scum is very light – and triturate it in the mortar. Thus dissolve the alkanet by grinding in the scum and it will give off its essence. Then take the brilliant color prepared by the dyer – if from kermes it is better, or else from krimnos – heat, and put this liquor into half of the scum in the mortar. Then put the wool in and color it unmordanted and you will find it beyond all description.

102. Dyeing in Good Purple

Take the wool and clean with soap weed. Then mordant it in filtered limewater. Boil it then in alum and water. This should, however, be sharp acetous alum. Then boil it according to the pro-

cedure for mordanting with urine. Next, unravel it. Rinse it out with water, then with salt water, and lay it aside.

103. (No Title)

For a stater of wool take a kotyle of urine (and) put in the bowl with the urine and mix there, 4 drachmas of alkanet bark, 1 drachma of native soda (and) 1 drachma of raw Cyprian misy until it appears to you to be good. However, take away the first scum, which is white and untouched by the mixture. But when the essences of the substances appears to have gone from them, then lift the basket up and press it out properly in the basin. Throw the substances away, but put the mordanted wool in and produce (the) purple on it. Make a test beforehand (that is), put a flock of wool in underneath (the surface) with the hand and look at it. The vessel in which the boiling is done should. however, on account of the frequent boiling over, contain sixfold (the volume). When the wool is suitable then hang and drain it until you have obtained the luster.

104. Collection of Woad

Cut off the woad and put it together in a basket in the shade. Crush and pulverize, and leave it a whole day. Air thoroughly on the following day and trample about in it so that by the motion of the feet it is turned up and uniformly dried. Put together in baskets lay it aside. Woad, thus treated, is called charcoal.

The last word in the recipe probably referred to its appearance. It occurs again in the title of No. 106.

105. Dyeing in Dark Blue

Put about a talent of woad in a tube, which stands in the sun and contains not less than 15 metretes, and pack it in well. Then pour urine in and the liquid rises over the woad and let it be warmed by the sun, but on the following day get the woad ready in a way so

that you (can) tread around in it in the sun until it becomes well moistened. One must do this, however, for 3 days together.

106. Cooking of Woad Charcoal

Divide the woad charcoal into three parts including that which is above the infused urine. Mix one of the parts in a convenient manner, put it in a pot and build a fire beneath it. You will perceive whether the wood is cooked in the following manner. When it boils, stir carefully and not m a disorderly fashion, so that the woad does not sink down and ruin the kettle. When the woad cracks in the middle the cooking is perfect. You should take away the fire from the underneath, but should nevertheless stir within the pot. Cool the under surface of the pot by sprinkling with cold water. Then take and put in the vat a half a choenix of soap weed. Pour enough of the cooked woad over (it), lay poles or reeds over the edge of the flat, cover with mats and build a moderate fire under it so that it does not boil over and (yet) does not become cold. Leave it 3 days. Boil up urine with soap weed, skim off the scum, and put in boiled wool. Then rinse off in a convenient manner, press out, card it, and put the wool in the dye liquor. When it appears to you to be right, take the wool out, cover up the flat again and build a fire beneath it in the same way. Put 2 minas of archil in the liquid, after you have boiled the archil and in doing so have skimmed off the scum. Then put the dyed wool in. Rinse off in salt water and cool it off. Dye in blue twice a day, morning and evening, as long as the the liquor is serviceable.

107. Dyeing in Rose Color

Rose color is dyed in the following way. Smear the rolls of wool with ashes, untie them, and wash the wool in the liquid from potter's clay. Rinse it out and mordant it as previously described. Rinse it out in salt water after mordanting and use rain water (which is so) warm that you cannot put your hand in it. Then take for each mina of wool a quarter of a mina of roasted and finely pulverized madder and a quarter of a choenix of bean meat. Mix these together by the addition of white oil, pour it into the kettle

and stir up. Put the wool in the kettle and again stir incessantly so that it becomes uniform. When it appears to you to have absorbed the dye liquor, however, brighten it by means of alum, rinse it out again in salt water, and dry it in the shade with protection from smoke.

108. Dyeing with Archil

To dye with archil. Wash the wool as is previously described. For a mina of wool take 4 chus of urine and a half a mina of alum. Mix these, and at the same time make a fire beneath them until they boil up. Put the wool in and stir incessantly, but when the wool sinks down and the liquor subsides then rinse the wool out. Boil in drinking water three times as much archil as the weight of the wool, take the archil out, put the wool in and stir up uniformly until the wool becomes soaked. Then pulverize a quarter of a mina of chalcanthum for each mina of wool and mix them. Stir up incessantly and thereby make the wool uniform. Then take it out, rinse out and let the wool dry as in other cases.

109. Dyeing in Phoenician Color with Archil

Roll up the wool and sift ashes over it. Separate the rolls in a convenient manner and again shift ashes over them until the wool becomes clean and branny. Shake it out on the following day and rinse it out. After the washing, boil it with 6 chus of salt water for each mina of wool, mix in half a mina of alum and mordant the wool therein in the way mentioned. Rinse it out. Then cook, in rainwater, until it boils, three times as much archil as the weight of the wool. Pour in goat's milk and stir up. Put the wool in and stir again until the color is thoroughly soaked in. Then take the wool out, rinse it and dry it, but in doing so protect it from smoke.

110. Dyeing in Bright Red Purple

To dye in genuine bright red purple grind archil and take 5 cyathi of the juice for a mina of wool. If you wish a bright tint mix in

ground natron (and) if you desire a still brighter one, chalcanthum.

111. The Book of Africanus: Preparation of Bright Red Purple

Take and put the mordanted wool into 1 choenix of krimnos and 4 choenices of archil. Boil these materials, put the wool in and leave it there unit later. Take it out and rinse it with salt water, then with fresh water.

112. Another (Recipe)

Pulverize and cook 4, drachmas of chalcanthum, 4 drachmas of Sinopian earth and 8 drachmas of krimnos. Put the mordanted wool in and it will become a fine deep red purple.

Sinopian earth apparently had several meanings. The description of Dioscorides (*Materia medica,* V, 3) is that of an iron ochre although the term sometimes meant red lead.

113. Another (Recipe)

Dyeing in purple with herbs. Take and put the wool in the juice of henbane and lupines. The juice should be brought to boiling in water, which thereby becomes sour. This is the preliminary mordant. Then take the fruit clusters of rhamus, put water in a kettle and boil. Put the wool in and it will become a good purple. Lift the wool out, rinse it with water from a forge, let it dry in the sun and it will be purple of the first quality.

114. Another (Recipe)

After the wool has been mordanted then take 20 drachmas of good Sinopian earth, boil it in vinegar and put the wool in. Add 2 drachmas of chalcanthum. Lift the wool out, put it in a kettle full of warm water and leave it there 1 hour. Lift the wool out and rinse it.

115. Dyeing of Various Colors

To prepare Phoenician dye. Take and combine heliotrope with alkanet. Lay them in an earthen vessel and sprinkle them for 3 days with white vinegar. On the fourth day boil them, with the addition of water, until these float at the top. If you desire, however, to dye cedar color then take out the alkanet, and boil lightly, but if you wish cherry-red then add krimnos soured with a little soap. Put the wool in and boil it together with the substances until it appears to you to be good.

116. Cold Dyeing in Dark Yellow

Put 1 part of golden litharge (and) 2 parts of quicklime in a vessel and pour water in until it runs over. Stir until it is mixed and put the rinsed-out wool in, which after a time receives another color. If you mix alkanet in with it, the wool becomes better.

117. Dyeing in Scarlet

Take the wool and mordant with woad, which dyes blue. Wash and dry it. Then take and crush kermes in water until it becomes dissolved. Then mix in rustic archil and boil thus. Put the wool in and it will become scarlet.

The exact sense of the word "rustic" in the above recipe is, according to Lagercrantz, that it refers to archil from the country as an inferior variety.

118. To Produce a Gold Color by Cold Dyeing

Take safflower blossom and oxeye, crush them together and lay them in water. Put the wool in and sprinkle with water. Lift the wool out, expose it to the air, and use it.

119. To Wash Raw Wool

The washing of raw wool is done in the following way. For a mina of wool take 9 minas of Cimolian earth, 2 kotyles of vinegar, and pour in water. Wash the wool therein and air thoroughly.

120. Examination of Dyestuffs

Heavy and dark blue wood is good, but the pure white and light (kind) is not good. The examination of Syrian kermes. Take and crush that which is the lightest and the most finely colored. The black or white-spotted is, however, poor. Chew into pieces with natron and dissolve up the finely colored. Pulverize the finest colored madder and thus make the test. Purple-colored and fast archil is as if snail-colored, but the white-spotted and black is – take notice – not good. Now if you chew genuinely colored archil into pieces then take and hold it in the hand (to examine it). Alum should be moist and very white. That which contains saltiness is, however, unsuitable. Concerning flowers of copper, that is suitable which shows a dark blue color, a very green leek color or, in general, a fiery fine color.

121. Dyeing Canusinian Wool

Boil, beforehand, in a leaden kettle 20 drachmas of krimnos, 8 or else 12 drachmas of thistle, (and) 1 chus of water for 1 mina of unmordanted wool. Then put the wool in, make a sample and it will be Canusinian wool.

122. Dyeing of a Color

Take heat-dried quicklime and golden litharge, grind both substances in an earthen vessel and stir up. Put the wool in, leave it there a day and a night and the color will come up on it. You should rinse it off with soap weed. When it has been rinsed and you desire (to color) it further, then after the bath, dye it again in the aforementioned dye liquor.

123. Dyeing in Purple

Bright red purple; juice of archil. If you desire a deeper shade then put in natron. If you desire a still deeper, (then put in) chalcanthum.

124. Another (Recipe)

One dyes an indelible purple by means of braids of seaweed with water.

125. Another (Recipe)

Purple which does not fade. Boil seaweed with archil and vinegar and put the wool in uniformly.

In the two above recipes the species of seaweed or algae used is not stated. Certain kinds can be used for this purpose, however.

126. Another (Recipe)

Red ochre dissolved in vinegar produces purple.

127. Another (Recipe)

Alkanet, madder, archil. and calves' blood dye purple.

128. Another (Recipe)

Purple. Phrygian stone is crushed and boiled. The wool is put in and left there until it becomes cold. Then lift it out. Put in another vessel 1 part of archil and 1 part of amaranth blossom, boil it again, put the wool in and leave it become cold there. Lift it out and rinse it with salt water. An excellent mordant for purple comes from Phrygian stone; for a kotyle of wool (use) a kotyle of stones.

129. Another (Recipe)

Cold-dyed purple. Pulverize quicklime in cistern water. Pour the lye off and mordant what you wish therein from morning until evening. Then rinse it out in fresh water (and) color it in the first place in an extract of archil. Then put in chalcanthum in addition.

130. Dyeing of Dark Yellow Wool

Dyeing of all kinds of dark yellow wool so that it appears as if this were its color. Grind golden litharge finely and put a little of it in a clean vessel together with four times as much lime. Pour fresh rain water upon these so that it covers them and stir thoroughly until they are well mixed. Rinse the wool out beforehand and now put it in. After a time it indeed gains another color, so that it appears as if this were natural and wonderful.

131. Dissolving of Archil

Take and wash archil properly, air it and lay it aside. Then take and cook bean chips in considerable water. When they are well cooked, then mix archil with the water from the bean chips. When you let the archil become cold together with this, then you will dissolve it in this manner.

132. Dissolving of Alkanet

Take decorticated and pulverized alkanet and add the interior of Persian nuts. Pulverize these again and add a little lamellose alum. Grind everything together while moistening with water. Make a lump out of it, place it aside and leave it to imbibe color. Then take a vessel of water, put the lump in the water, stir up and leave it unbroken. Put your finger in and if the color is beautiful then use it

133. Preparing Genuine Purples

Iron rust, roasted misy, and pomegranate blossom adapt themselves to mordanting in water and make it possible to give the wool a good deep purple color in 4 hours.

134. Another (Recipe)

Let iron rust soak in vinegar for as many days as is necessary. Then mordant the wool in this liquor, which should be cold. Then boil krimnos and put the mordanted wool in.

135. From Book 3 of Africanus

Mordanting for any color is done in the following way. First the animal, or else likewise only the wool is washed; then one can allow the mordanting agent upon it. One should then dissolve alum in vinegar and coat the wool, which one desires to dye, with it. After drying in the sun, it is washed, and when it is freed from its moisture admit it to any coloring. One must pay attention to that which is mordanted for a day and a night during the mordanting.

136. Dyeing of Colors

Lime, which is mixed and ground with litharge, produces many colors, yet in such a manner that the wool does not retain them. First, milk-white, then natural; and then deep by means of cold dyeing.

137. Mordanting for Every Color Except Purple

Dissolve alum in vinegar, add raw misy, and use it.

138. Mordanting for Purple

When you mordant for purple, then put in pure sulphur in lumps in addition, so that the purple (by trial) gains a brilliant shade; but in

case it does not become bright (it is) because it contains something related with what one tests it with.

139. Dyeing of Colors

By celandine one means a plant root. It dyes (a) gold color by cold dyeing. Celandine is costly, however. You should accordingly use the root of the pomegranate tree and it will act the same. And if wolf's milk is boiled and dried it produces yellow. If, however, a little verdigris is mixed with it, it produces green; and safflower blossom likewise.

140. Dissolving of Alkanet

Alkanet is dissolved with the root of henbane. Some cook it with the root of the mulberry tree, others likewise with the root of the caper bush. Some cook alkanet with lentils, others with pellitory root.

141. Fastness of Alkanet

Sheep's urine, comarum, or henbane are equally good.

142 Fastness of Archil and Alkanet

Extract of leaves of the citron tree; extract of barley and navel-wort; and onion juice. Each of these substances alone make (them) fast.

143 Dissolving of Comarum

Take and soak pig manure with the urine of an uncorrupted youth. Boil up these and pour it off on the comarum.

144 Another (Recipe)

Dissolve calcined marble in cold water, put comarum together with it in milk and the comarum will become dissolved.

145. Cleaning by Means of Soap Weed

Take and treat soap weed with hot water. Make a ball from it as if from tallow. Then steep this in hot water until it is dissolved. The water, however, should go above the wool. Then boil up the water. Put the wool in and prevent it from becoming scorched. Leave it there a little while until you see that it is clean. Lift out, rinse it and dry it.

146. Mordanting

Then take lime and hot water and make a lye from it, let it stand and take away thereby the impurity existing upon it. When you see that the water has become crystal clear, then put the wool in, shake and leave it there again a little while. Lift it out and rinse it.

147. Boiling (Wool)

Then take two kotyles of fresh water and 8 drachmas of acetous alum for a stater of wool. Put the water, the alum in a small basket, and some barleycorn into the kettle and place it upon the fire until the barleycorn is cooked and the alum has dissolved. Take away the impurity existing in the liquid, put the wool in, dip it under and separate it with the rake. Arrange it uniformly, put on the cover and heat the kettle until you see that the wool is puffed up. Then lift it out, hang it up, again perform the same operation with the rake and heal the kettle. When it is to be taken out, then remove the kettle from the fire, hang the wool up and let it drain until you undertake the mordanting with the urine.

148. Preparation of Tyrian Purple

Phrygian stone is pulverized and boiled. The wool is put in and left there until it becomes cold. Then lift it out and put a mina of archil in a vessel, boil it, put the wool in again and let it become cold there. Lift it out and rinse it with salt water.

149. Cold Dyeing of Purple

Pulverize and dissolve quicklime with rain water, strain the water and mordant therein from early morning until late (in the day). Do not rinse out with salt water but with fresh water. Then dye with boiled archil. Then put in chalcanthum besides and the purple will come forth from it.

150. Dyeing of Galatian Scarlet

Alkanet and archil, 1 ounce each, 2 ounces of swine's blood; 5 drachmas of chalcanthum; 2 drachmas of roasted orpiment; 8 pints of water.

151. Dyeing of Tyrian or Guaranteed Superior Purple

Seven drachmas of alkanet; 5 drachmas of orpiment; 1 ounce of urine; 5 drachmas of quicklime; 1 kotyle of water.

152. Shading Off of Colors

When you desire to shade off the brightness of a color then boil sulphur with cow's milk, and the color will be easily shaded off in it.

153. Dyeing of Madder Purple

After bluing, sprinkle the wool with ashes and trample it down with them in a convenient manner. Then press (the) liquid out of potter's clay and wash off the blued wool therein. Rinse it in salt water and mordant it. You will know if it is sufficiently mordanted when it sinks down in the kettle and the fluid becomes clear. Then heat rain water so that you cannot put your hand in it. Mix roasted, pulverized and sifted madder root, i. e., madder, with white vinegar, a half a mina of madder to a mina of wool, and mix a quarter of a choenix of bean meal with the madder root. Then put these in a kettle and stir up. Then put the wool in, in doing so, stir incessantly and make it uniform. Take it out and rinse it in salt water. If you wish the color to take on a beautiful gloss and not to fade, then

brighten it with alum. Rinse the wool out again in salt water. let it dry in the shade and in doing so protect it from smoke.

154. (No Title) (On a separate leaf from the rest of the recipes)

Sun, Berbeloch, Chthotho, Miach, Sandum, Echnin, Zaguel, accept me who comes before thee. Trust thyself (to the God), anoint thyself and thou shalt see him with thine eyes.

3.3 Commentary

The excellent translations of the Stockholm Papyrus into modern Greek and German by Lagercrantz leaves little to be desired in the way of a philological and etymological commentary. This translator, however, did not enter into the general and technical significance of the recipes of the collection. It is the purpose of these few paragraphs to discuss this phase of the collection in the briefest way possible, since space does not permit the extended treatment of these matters that could be given, especially in comparing them with the other authors and works in early technical arts, and in discussing their value for the early history of alchemy and technical chemistry.

It is very evident that the recipes in the collection can be grouped into three main classes. The first few deal with the manufacture of alloys and are nearly identical with those of this type that occur in the Leyden Papyrus X. On account of this similarity no further comments are needed upon them here. The second type deals with the cleaning and imitation of gems and precious stones, while the third group includes those treating of the various arts connected with the dyeing of cloth. These two groups will now be discussed separately.

There are exactly seventy-one recipes that deal with the cleaning and imitation of precious stones or with closely related operations. Ten of these, most of which follow immediately after the recipes for alloys, deal with cleaning genuine or making artificial pearls. The cleaning methods used were largely empirical in their nature. One method was to coat the pearl with some suitable glutinous

mixture, then to peel this off again. This latter operation apparently removed the objectionable dirt. Recipe No. 61, in which lime is employed in this manner, apparently contains some rudimentary attempt at chemical theory. Various liquids were also employed in cleaning. Perhaps the most curious and the least scientific of these cleaning methods is that described in Recipes No. 25 and 60 in which the pearl is given to a fowl to eat and is afterward recovered and found to be cleaned. This set of recipes contains the first account of the manufacture of imitation pearls. Recipe No. 18 describes their preparation in which shimmering scales from mica or ground selenite were incorporated in a paste made from gum, wax, mercury, and white of eggs. This was then shaped and dried, probably yielding an inferior imitation of the real thing, although the last sentence of the recipe assures us otherwise. Recipes No. 22 and 23 detail other methods of accomplishing the same end.

The remainder of the recipes of the second group deal with the imitating of emerald, ruby, beryl, amethyst, sunstone, and other valuable gem stones. The base for nearly all of these imitations is the so-called crystal. This word in Greek is generally understood to mean quartz or rock crystal. Probably, however, its meaning in the papyrus was extended to other clear stones, notably to selenite, since the processes used depended somewhat upon having more easily corroded stones than quartz. At any rate, the first step in the manufacture of imitation precious stones, as practiced in ancient Egypt, was to treat the base used in such a way as to roughen it and to make the surface of the stones porous. Various substances and methods were used for this purpose. The heated stones were generally boiled or dipped in oil, wax, or solutions of alum, native soda, common salt, vinegar, calcium sulfide, or in mixtures of these. By this means the surface of the stone used was roughened and also, probably to some degree, mordanted for the application of dyes. After corroding or mordanting the stone in this manner some kind of a dyeing material was then applied. These latter fall into two classes, the inorganic and the organic substances. Copper salts, for example, were usually applied to form imitation emeralds from the base, while alkanet was used for red stones. Recipe No. 74 is of special interest in that it gives the method of preparing verdigris for this very purpose. This is probably the first detailed laboratory

direction for the preparation of a chemical salt. Many vegetable dyes and other organic substances were employed in dyeing the treated crystal, among which were alkanet, celandine, cedar oil, pitch, and various resins. In some cases the two operations were combined in one.

It is to be remarked that many of the recipes carry various detailed precautions concerning the processes, showing the presence of much experience in carrying them out. We may well question the beauty and the permanency of the imitation gems prepared by these methods, but probably they satisfied the people of that period. These methods of imitating precious stones seem to imply strongly that the manufacture of colored glasses was not a developed art at the time of this collection and came at a later period.

The remainder of the recipes in the collection deal with a subject which was equally important in ancient times as it is with us, namely, the methods of dyeing or coloring cloths. The recipes of this collection and the few of the Leyden Papyrus are the earliest specific directions for the use of dyes. A glance over the recipes on this topic shows plainly that the art of dyeing was well understood from the practical standpoint. The first step in the dyeing process was the cleaning of the cloth to free it from dirt and grease. The various cleaning agents employed included native soda, soap weed, and others. That the importance of mordanting was well recognized is evident from the many recipes on the subject. The materials used included alum, limewater, iron and copper compounds, and some vegetable substances. There is no doubt that the theory of their use was but faintly understood, but there can be no question about their understanding of their practical use.

The dyes used included alkanet, archil, woad, madder, and other less common ones together with various combinations of those named. It is evident from the recipes that purple was the favorite color in ancient Egypt at the time of this collection, but it is to be remembered, however, that this term then included red and some other shades also. One thing that the recipes on purple do show, however, is that the purple of the ancients was not obtained exclusively from a certain species of shellfish as has been generally

believed. Other colors mentioned include blue, yellow, and scarlet. The use of different rinsing solutions and the preparation of some of the dyes used is also described in this collection. The remarkable nature of these recipes on dyeing as practiced in ancient times is seen when we remember that the methods mentioned here were essentially the ones used for a period of fifteen hundred years after, or up until the advent of our modern coal-tar dyes.

We are always somewhat interested in the personalities connected with any period or development of human knowledge and we may well ask ourselves as to the author or authors of the Stockholm and Leyden Papyri. The Leyden Papyrus X gives no hint as to its authorship, but the Stockholm Papyrus at least gives us some hint as to the probable character of the writer. The last recipe in the collection is on a sheet separate from the remainder and is not numbered like the other sheets. It contains a magical or theurgical formula entirely different from the other recipes. If it belonged to the owner of the remainder of the collection – and it is probable that it did – then it tends to show that chemical arts in ancient Egypt were largely in the hands of the priestly caste, a fact that has been deduced from other sources and of which this is the earliest direct evidence yet shown. The collection also mentions several names of early workers in chemical arts, and indeed quotes from them, Africanus and Democritus in particular. In conclusion, then, it can well be said that from whatever angle we may view both the Stockholm and the Leyden Papyri there can be no question but that these earliest chemical manuscripts contain material of the greatest value for the history of the beginnings of chemistry.

3.4 References and Notes

1. O. Lagercrantz, *Papyrus graecus Holmiensis: Recepte für Silber, Steine und Purpur,* A.-B. Akademiska Bokhandeln: Uppsala, 1913.

IV
A Note on Technique

4.1 Ancient Technologies

As suggested by Caley in his description of the Leyden papyrus, it is highly probable that many of its recipes (and those of the Stockholm papyrus as well) were copied from far older sources which have failed to survive. The few references, both implicit and explicit, to such writers as pseudo-Democritus (c. 200 BC), Dioscorides Pedanius (c. 1st century AD), and Julius Africanus (c. 220 AD) push the story back by only a few centuries, after which the written trail goes cold. But however limited our ability to document the earlier history of these recipes, the same is not equally true of most of the various manipulative techniques which they employ, such as the use of balances to weigh ingredients, the use of charcoal furnaces, blowpipes, and bellows to melt and cast metals, or the use of mortars, pestles and sieves to grind and sift solids. As testified to by actual surviving artifacts and by numerous Egyptian tomb paintings, it may be easily shown that many of these preparative techniques predate the Leyden and Stockholm papyri by several thousand years.

Some pertinent examples are reproduced on the following four plates in the form of woodcuts taken from the lavishly illustrated two-volume work, *A Popular Account of the Ancient Egyptians*, published by Sir J. Gardner Wilkinson in 1853 (1). These have been used in lieu of photographs of the original paintings both because of ease of reproduction and their greater clarity. Wilkinson was none too specific about the location of the original paintings on which these drawings were based. However, consultation of the booklet by Wilkinson and Hill on facsimile Egyptian tomb paintings in the possession of the New York Metropolitan Museum of Art, shows that most of them were based on paintings found in either the tomb of Rekhmira at Thebes (c. 1475 BC), which depict the craftsmen of Amun in the workshops

of the temple at Karnak, or from the tomb of the royal sculptors, Nebamun and Ipuky, also at Thebes (c. 1380 BC), which depict royal metal and wood artisans at work (2). This means that the paintings in question predate the Leyden and Stockholm papyri by between 1700-1800 years. Thus, one may infer that, however much the written language, religion, and dress of the Egyptians may have changed in the centuries separating the Dynastic period from the Greco-Roman period, certain fundamental features of basic everyday technology appear to have remained essentially unaltered.

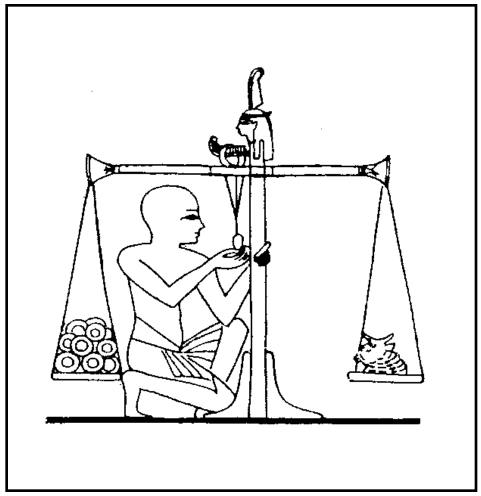
The importance of this somewhat trivial observation, however, lies less in the simple everyday techniques and apparatus which are mentioned in the papyri, than it does in those which are not mentioned – namely the *alembic* and the *tribikos* for distillation, and the *kerotakis* for sublimation and the exposure of metals to volatile vapors – all of which are highly characteristic of that branch of the true Greco-Egyptian alchemical literature which is derived from the writings of Maria the Jewess, and of most of the later alchemical literature as well, with its persistent preoccupation with the separation and manipulation of the seminal essences or generative forms of materials (3). Thus the Leyden and Stockholm papyri are not only lacking the allegorical and theoretical content typical of the true alchemical literature, they are also lacking many of its most characteristic laboratory techniques. As noted many years ago by Hammer-Jensen, the same may be said of the materials used in the papyri, which refer to the use of sulfur and sulfur water in connection with the recipes for metal alloys only twice (actually four times), whereas the use of these materials is ubiquitous in the true alchemical literature, including that branch supposedly derived from the *Physica et Mystica* of Bolos of Mendes (4).

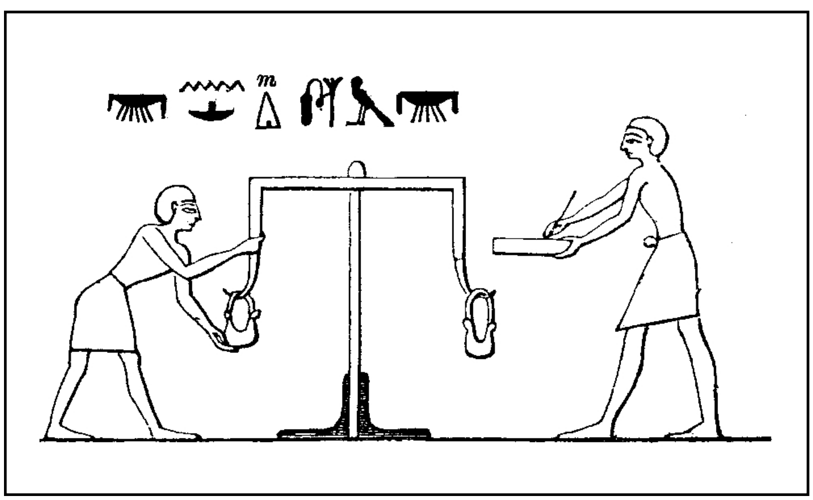
4.2 References and Notes

1. J. G. Wilkinson, *A Popular Account of the Ancient Egyptians*, Vol. 2, Murray: London, 1853, pp. 137, 139, 166.

2. C. K. Wilkinson, M. Hill, *Egyptian Wall Paintings, The Metropolitan Museum of Arts Collection of Facsimiles*, Metropolitan Museum of Art: New York, NY, 1983, photographs 33, 53, 59 and catalog items 30.4.103, 31.4.2, 31.6.11, 31.6.17, 31.6.22, 31.6.24.

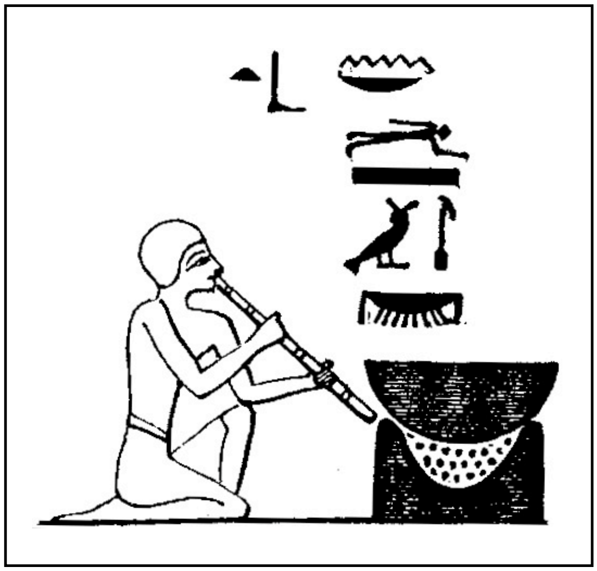
PLATE I

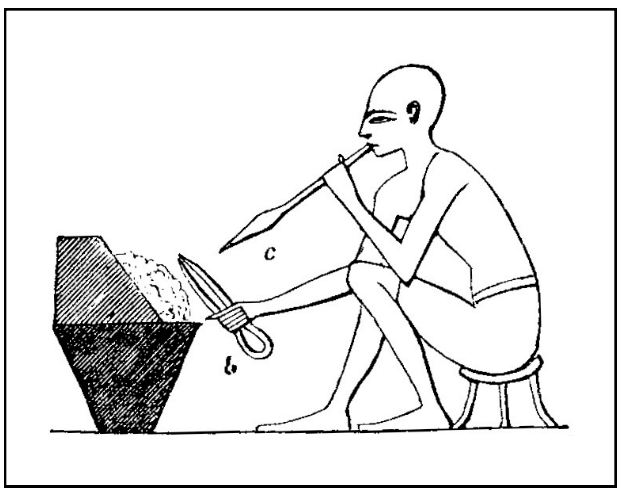




Two depictions of the use of the double-pan suspension balance by the ancient Egyptians to weigh various commercial products. The author of the Leyden and Stockholm papyri would have used a similar balance to measure the ingredients in his recipes in units of drachmas, staters, mina, etc.

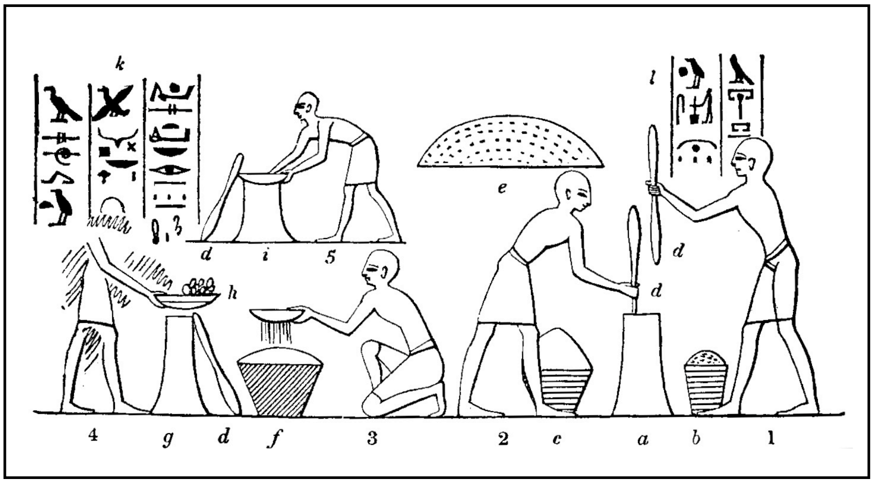
PLATE II

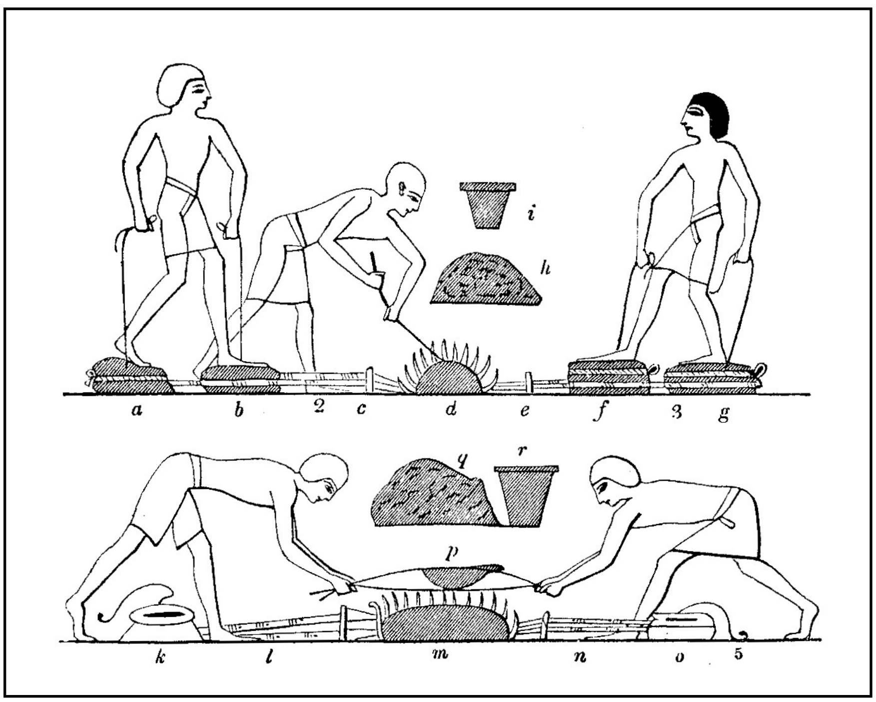




Two depictions of the use of the mouth blowpipe by the ancient Egyptians to intensify the heat of a charcoal fire for purposes of either melting or working metals. The author of the Leyden papyrus would have used a similar device in order to properly melt the metals required to make the various alloys described in the recipes and makes specific reference to its use in recipe 22.

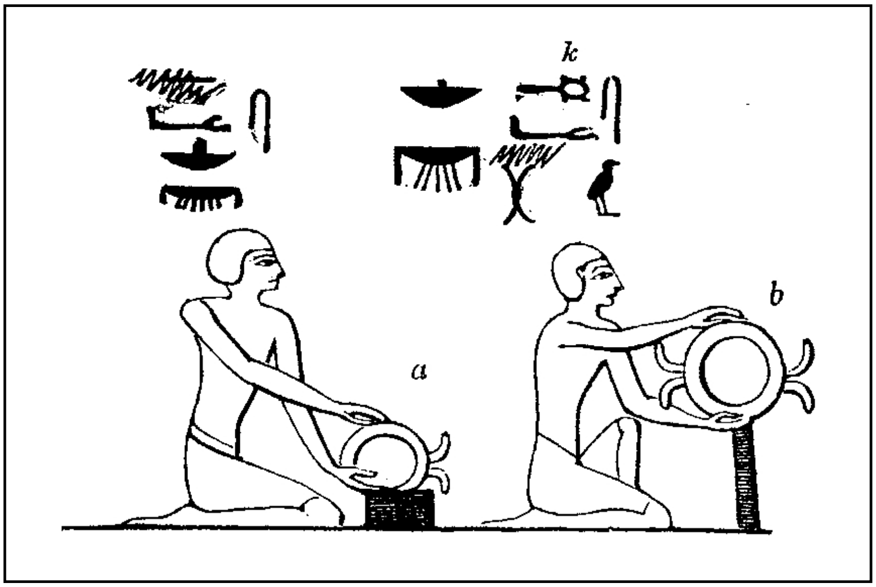
PLATE III

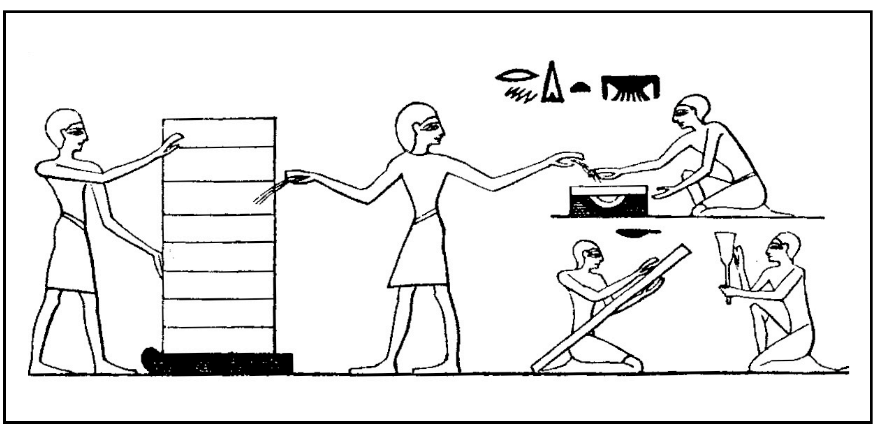




Above: The use of mortars, pestles, and sieves to produce finely ground materials similar to those specified in many of the recipes. *Below:* The use of foot-bellows and crucibles to produce the high-temperature fires required for the melting and casting of metals.

PLATE IV





Two illustrations depicting the finishing of gold jewelry (above) and the making of gold leaf (below) for the gilding of various objects by the ancient Egyptians. Many of the recipes in the Leyden papyrus were intended to produce cheap substitutes for pure gold and several of those for metallic inks specify gold leaf as one of the required starting materials.

3. For a readable account of some of this apparatus, see F. S. Taylor, "A Survey of Greek Alchemy," *J. Hellenic Stud.,* **1930***, 50(1),* 109-139 and F. S. Taylor, "The Evolution of the Still," *Ann. Sci.*, **1945**, 5, 184-202.

4. I. Hammer-Jensen, *Die älteste Alchymie*, Host & Son: Copenhagen, 1921.

V

Materials Index

Key: Ld = Leyden papyrus, St = Stockholm papyrus, numbers refer to recipes and not to pages. Bitumen and pitch are listed under mineral origin since they are not harvested from living organisms, though ultimately of plant and animal origin. The undifferentiated term "oil" is assumed to be a vegetable oil of some sort rather than a mineral oil. Likewise wax is assumed to refer to bee's wax rather than to a wax of either plant or petroleum origin.

Mineral Origin

MATERIALS INDEX

Plant Origin

Animal Origin